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 CONTENTS OF VOLUME XXII.

	PAGE.
Papers and Notes read before the Society	iii.
Officers and Council of the Society	iv.
<i>Journal</i> No. 1.—July, 1921	1
.. .. 2.—August, 1921	21
.. .. 3.—September, 1921	29
.. .. 4.—October, 1921	45
.. .. 5.—November, 1921	73
.. .. 6.—December, 1921	97
.. .. 7.—January, 1922	117
.. .. 8.—February, 1922	145
.. .. 9.—March, 1922	165
.. .. 10.—April, 1922	177
.. .. 11.—May, 1922	205
.. .. 12.—June, 1922	237
Index to <i>Journal</i>	265

PAPERS AND NOTES READ BEFORE THE SOCIETY.

	PAGE.
Acidity of Mine Waters, The, by F. W. WATSON and R. A. COOPER, 30; Discussion, 159; Reply to Discussion	230
Coal Pillar Extraction from Two Seams and Surface Effects, by W. T. HESLOP, 54; Discussion, 61, 88, 160; Reply to Discussion	231
Combustion of South African Coals in Boiler Furnaces, The, by E. P. REIM, 117; Discussion, 192; Reply to Discussion	258
Correlation of Metallurgical Statistics, The, by H. A. WHITE, 97; Discussion, 192; Reply to Discussion	258
Development of the Blast Furnace, The, by J. HENDERSON, 178; Discussion	183
Endless Rope Haulage at Modder East, The, by J. CHILTON, 184; Discussion	187
Features of Metallurgy of a Refractory Gold Ore, by F. WARTENWEILER, 147; Discussion	152
Gold Precipitation by Zinc Dust and in Conjunction with the De-aeration of Solution at Modderfontein "B," by S. NEWTON and L. L. FEWSTER, 249; Discussion	258
Kata-Thermometer and its Practical Uses in Mining, The, by H. J. IRELAND (Addendum)	21
Notes on Osmiridium, by J. R. THURLOW, 209; Discussion	210
Notes on the Manipulation of Osmiridium Concentrate, by R. A. COOPER, 152; Discussion	151
Presidential Address, The, by F. WARTENWEILER	48
Resume of Standard Methods in Sampling, Analysis and Classification of Coal, A, by A. TREVOR WILLIAMS, 1, Discussion, 155, 189, Reply to Discussion	157
Some Notes on the Pilgrim's Rest Goldfields, by H. C. F. BELL, 79; Discussion, 85, 160, Reply to Discussion	231
Symposium: Miners' Phthisis, Contributions by H. R. ADAM, 225; W. ALLEN, 25; C. J. GRAY, 225; W. E. GYE, 222; A. MAVROCORDATO, 226; J. MOIR, 230; A. J. ORENSTEIN, 220, 221, 228; J. WATSON, 33; H. A. WHITE, 226; H. R. S. WILKES, 225; J. A. WOODBURN	32
Technical Examination of Lubricating Oil and Grease by F. W. WATSON and H. D. BELL, 211, Discussion	219
Waste Rock in Ore Milled, by W. A. CALDECOTT, 61; Discussion, 160; Reply to Discussion	191

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1

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Vol. XXII

JULY, 1921.

No. 1.

A RESUME OF STANDARD METHODS IN SAMPLING, ANALYSIS AND
CLASSIFICATION OF COAL.

By A. TREVOR WILLIAMS, M.Sc., B.A.

This paper is presented with a view of providing a resumé of recent work carried out on coal analysis by reliable authorities in England and America.

In itself it is hoped that the paper will be found useful in giving a fair insight into the contents of the more detailed works from which the references have been abstracted; if it kindles a desire for more exhaustive information, the enumeration of the references may offer themselves as a useful index.

Generally speaking, recent research work on coal has been of a two-fold nature. On the one hand that of the progressive and scientific investigators has been essentially more concerned with the very complex chemical structure of coal, whereas the industrial analysts have been more concerned with the perfection of methods of analysis which will enable a measure to be made of the utility of coal in the light of present-day practices.

The method of taking a sample of coal and the determination of the ash content and calorific value are so vital that it is thought advisable to emphasise the details as employed by present standard methods, which must be standard if genuine value is to be attributed to the results so obtained.

The paper will be opened up under three main headings:—

1. Sampling.
2. Analysis.
3. Classification.

and will be concluded with an Appendix.

1. Sampling.

To emphasise the fundamental import of correct sampling, one might quote the remarks of Mr. E. A. Barrow, President of the Locomotive and Coal-burners Coal

Research Association, who in the preface to a bulletin, published under the auspices of the above-named Association, by its director, Mr. F. S. Sinnatt, in 1919, on "The Sampling of Coal" (¹), states:—

"The sampling of coal is the most vital feature in arriving at its true value, and unless merchants, consumers and collieries agree to a standard method it is useless to attempt to buy and sell coal on the basis of its calorific value and chemical analysis."

In this he is unanimously supported by all reliable authorities. It is thought that it would be of interest to bring together the opinions expressed on this matter by English and American research associations and authorities.

The bulletin referred to (*loc. cit.*) is probably the most recent publication on this subject, based on actual research and enquiry, and for this reason much that is important in it has been abstracted.

Herein, regarding "the principle underlying sampling and its possible errors" it is stated that

"To be truly representative of the whole weight of any consignment of coal, a sample should not only contain a portion from every different part of the coal, but also the correct proportions of large and small coal and of large and small pieces of foreign matter and impurities."

The errors introduced by the above requirements being overlooked are far greater than those possible by even skilled chemical analysis. As emphasising the degree of error which is possible, Sinnatt says:

¹ F. S. Sinnatt, "Sampling of Coal," 1919.

"An engineer responsible for a boiler installation was invited to submit a sample of the coal he was using for analysis. Permission was then obtained to take a truly representative sample of the same coal, the following results were obtained:—

Ash present in engineer's sample	5
Ash present in representative sample	15

Probably most errors can be traced, directly or indirectly, to an under-estimated notion of what the weight of a sample ought to be.

Generally speaking, the wider the variation in sizes of the pieces of coal, the larger must be the sample. This also applies to foreign matter.

In confirmation of this point, work by Bailey (2) may be quoted, which shows that the weight of the sample should bear a direct relationship to the largest piece of foreign matter present, and to ensure an error of less than 1% in the ash present in the sample the following must be adhered to:—

Size of largest piece of shale. in.	Weight of largest piece of shale. lb.	Original Sample must weigh. lb.
4in.	6.7	39,000
3in.	2.5	12,500
2in.	0.75	3,800
1in.	0.12	600
0.75in.	0.046	230
0.50in.	0.018	90

"As a rule," states Sinnatt, "it is considered that the gross sample should be from 1/40th to 1/80th of the total weight of coal."

This rule is quite satisfactory so long as the gross sample does not exceed about 1,000 lb. When it exceeds that amount, the inaccuracies introduced during crushing, mixing and the quartering of the sample become excessive.

Difficulty will be experienced in determining the most suitable weight for the gross sample, but it should be assumed that the smallest weight is 1,000 lb. for

bulks weighing about 100 tons. The weight of the sample should not be reduced much below 250 lb. per 10 ton truck, for assuming an average shovelful to weigh 15 lbs., this only means 16 units collected per truck.

In obtaining the gross sample great care must be exercised to ensure the presence in it of the proper proportions of large and small coal and large and small impurities.

This may be checked approximately by carrying out a test before the sample has been crushed, to determine what proportion of the sample will, say, pass through a sieve of $\frac{1}{4}$ in. mesh. This test indicates the proportion of small coal present in the consignment, it also forms one of the simplest checks on any further deliveries, for if the percentage of fine coal differs widely from that present in the original sample, then variation in the quality may be expected."

The methods of taking a sample.—These may be confined to two cases, the first typifying the sampling from a mass—such as a heap or a truck—and the second, sampling from a mine seam.

In regard to the first case, it is fatal for a sampler to try and pick an average sample by taking what seems to him a fair proportion of the coarse and fine and neglecting materials that look either exceptionally good or bad. The only way is to determine how a most representative sample may be secured in a reasonable manner, and then to carry out the operation as mechanically as possible.

If the sample is being taken from a wagon the shovel should be run along the bottom of the wagon after enough has been unloaded to allow the coal to assume its natural shape. Where cars or wagons are being dumped a scoop may be held in the stream of falling coal. This essentially means collecting successive small increments from successive parts of the heap and provided discrimination is used as to the relative quantities of lump and fines the method has every claim to accuracy.

Mine or Seam Sampling.—Sinnatt states: "When samples are required to represent a seam of coal by far the most satisfactory solution is to cut a pillar of coal through the whole depth of the seam about 6 in. wide and from 6 in. to 8 in. deep, and including a portion of the roof and floor. This is then placed in a box constructed for the purpose, slightly larger than the pillar

(2) Bailey *Journ. Ind. and Eng. Chem.*, 1, 176, 1909.

of coal, and the whole kept in position by wooden wedges and clean straw. Each break in the coal should be marked in with a white number from the roof to the floor."

This differs in detail from the recommendation of the U.S.A. Bureau of Mines, which has been fully described by Holmes⁽³⁾. He recommends that for mines shipping 200 tons or less daily at least four samples should be taken. In general only clean fresh coal should be taken, and weathered coal should be avoided. Before cutting a sample the face of the bed and the roof is to be cleaned of those fragments which might drop into the sample, and a band 1 ft. wide extending from floor to roof is to be cut back at least an inch to expose fresh coal. The sample as cut from this prepared face should include everything the miner includes in the coal prepared for the market, and should exclude the thick partings and large lenses of pyrites which are thrown out by the miner. The cut should be made perpendicularly about 2 in. deep and 6 in. wide so that there will be about 6 lb. of coal chips for each foot of thickness of the seam. These chips are to be caught on a water-proof sample blanket and crushed to pass an $\frac{1}{2}$ in. screen and then placed in a tight sample can. All operations are to be carried out at the face.

Treatment of the sample.—During the period of collecting, the sample should be stored in a situation which is free from dust (especially coal dust), rain, draughts, and not liable to rapid changes of temperature. A covered barrel or box is suitable for the purpose.

After the sample has been obtained it must be mixed frequently and efficiently, and crushed at intervals. It is a great convenience, therefore, to place the sample upon a sheet non-sampling plate on which it is possible to crush the coal. A "punner" or large hammer will be found to be one of the most handy forms of coal crushers for this coarse grinding. The process of crushing, etc., should not be carried out on a brick or stone floor if there is any chance of foreign matter being introduced from this source. A second method is to place the whole of the sample in a thick canvas cloth sheet or tarpaulin, on which it may be

crushed by means of the "punner" or hammer; the coal may also be mixed by bringing the corners of the sheet across and back again and repeating the operation a number of times.

To ensure perfectly unbiassed mixing of the gross sample, and at the same time to reduce its weight until it is convenient for the laboratory, the process of coning and quartering usually adopted in reducing bulk samples must be rigidly observed.

In carrying out the above operation it is necessary to crush the coal as the weight of it decreases.

"The following table," states Sinnatt (*loc. cit.*)⁽⁴⁾ "shows the size to which the sample should be broken in order to eliminate errors during the reduction of the weight of the sample"—

Weight of sample to be quartered. lbs.	Greatest size of pieces of coal and foreign matter.
3,800	1 $\frac{1}{2}$
1,200	1
460	$\frac{3}{4}$
180	$\frac{1}{2}$
40	2 mesh
5	4 "
$\frac{1}{2}$	8 "
$\frac{1}{4}$	10 "

Laboratory Sample.—The above principle cannot be ignored in the laboratory, and the following are the limits beyond which samples should not be quartered for various sizes of the pieces of coal:—

Weight of Sample should not be less than grams.	Size of coal (mesh).
8,300	2
1,100	4
120	8
55	10
3	20

When the weight falls to about 40 lb. samples may be sent to the laboratory, or be crushed so as to completely pass through a sieve of four meshes to the linear inch, when its weight may be reduced to 15 lb.

It should then be divided into three portions, the first for the laboratory, the second

(3) Holmes—(Technical paper 1, U.S.A. Bureau of Mines, 1911).

(4) F. W. Sinnatt—(*loc. cit.*).

to be sealed and preserved in case of dispute, and the third to be sealed and preserved for examination by a neutral expert in case this becomes necessary for arbitration.

Samples may be preserved in porcelain or glass jars, fitted with patent air-tight lids; the samples used for analysis are, however, more conveniently kept in stoppered bottles. This is essential to prevent any variations in moisture, which readily occurs, particularly when coal is in a finely divided state.

The sample for use in the laboratory must be crushed so as to pass through a sieve of 20 mesh, and it is important to notice that in all grinding the whole of the sample must pass through the sieve.

The grinding of a small quantity can be carried out in a grinder of the type of a coffee mill, but care should be taken to obtain one which can be readily dismantled and permits of thorough cleaning.

For certain of the chemical determinations (*i.e.*, for the estimation of nitrogen and sulphur) it is convenient to have the coal in a very fine state of division, and a grinder which has been found to be very useful is a small ball mill. It consists of a porcelain cylinder about 6 in. in diameter and 8 in. long, partly filled with irregularly shaped porcelain balls. The cylinder may be made to revolve at any desired speed. If required, coal can be powdered so as to pass through a sieve of as fine as 200 mesh in a few hours. It is possible to grind coal in such a mill without continually exposing it to air, and in consequence little change in oxidation—which is a feature present when coal is finely divided—takes place in the sample during the process.

2. ANALYSIS OF COAL.

The standard determinations which are generally accepted as comprising a comprehensive analysis of coal are the following:—

The determination of—

1. Calorific value.
 2. Moisture percentage.
 3. Volatile matter and residual or "fixed" carbon.
 4. Ash percentage.
- (2, 3 and 4 being usually bracketted together under the heading of "Proximate Analysis of Coal").
5. Sulphur percentage.
 6. Nitrogen percentage.
 7. Ultimate analysis, giving the percentage of C, H, O and N.

The above are mainly percentage determinations, and so are merely quantitative; more recent work tends to expand and embrace mode of occurrence as well. It is not the intention in the present paper to consider, in any detail, either the apparatus or the operations employed: this has been done efficiently in many text books and most thoroughly by Prof. A. H. White in his book "On Gas and Fuel Analysis."

In the following the object is more to review the reliability of the accepted methods, and to indicate the precautions which it is essential to observe, before any claim to an adequate accuracy can be safely entertained.

1. *Determination of Calorific Value.*—Various types of calorimeter have been employed for the above determination, but at the present time the heating power of a coal is, one might say, determined entirely by means of the bomb calorimeter.

Among the methods which have now become obsolete, or practically so, might be mentioned—

(a) *Calorimeters employing a stream of oxygen to effect combustion.*—This method had for its chief source of error the, almost inevitable, incomplete combustion of the coal, and there was also the difficulty of measuring the temperatures of the incoming oxygen and the outgoing products of combustion.

(b) *The Lewis-Thomson Calorimeter.*—This instrument is well known, and at one time was used extensively. Combustion was effected by mixing the powdered coal with potassium chlorate and nitrate.

(c) *Parr Calorimeter.*—Prof. Parr's Calorimeter⁽⁵⁾ might be looked upon as a compromise between the Lewis Thompson and Bomb Calorimeters.

The inventor proposed sodium peroxide as a chemical to be used for providing the oxygen necessary to oxidise the coal in the calorimeter, worked out the corrections to be applied, and devised a very practical calorimeter.

The work of Prof. Parr has shown definitely that accurate results may be obtained with this calorimeter, but it has also shown that this accuracy can only be gained by the observation of the precautions and the use of corrections, which deprive the process of much of the simplicity which formerly characterised it. These points pre-

⁽⁵⁾ Prof. Parr—*Journ. Am. Chem. Soc.*, 1900.

vent the method from being a standard one—particularly as it involves the ash and sulphur determinations as well—but they do not exclude it from being a useful commercial instrument, where the highest accuracy is not needed.

The Bomb Calorimeter.—Without doubt the bomb calorimeter is the most accurate, reliable, and also convenient, apparatus for determining the calorific values of either solid or liquid fuels.

When care is taken in every detail and apparatus of superior quality is used, the agreement between duplicate determinations will be closer than 0.3 per cent. or 50 B.T.U., but it is certainly not safe to claim a closer absolute accuracy, since according to Jesse *Journ. Ind. and Chem. Eng.*, 1912 the highest authorities differ by 0.25 per cent. as to the absolute heating value of sugar and benzoic acid, which are used in determining the water equivalent. The oxidation of N. and sulphur deserve corrections amounting to about 8 B.T.U. each, but these are offset by the corrections necessary to correct for the combustion having been carried out at constant volume, whereas in practice combustion takes place at constant pressure.

Calculation from Proximate and Ultimate Analysis.—It appears convenient here to insert the useful formulae which have been derived for estimating the thermal value of a coal from a knowledge of its proximate or its ultimate analysis.

According to Prof. Cobb (Leeds University), if

(A) Ht represents the calorific value of the fuel

C, H, O, N and S represent the percentage of each of these constituents, and

W represents the percentage of hygroscopic water, then

$$Ht = 81C + 2900H - \frac{O + N}{8} + 25S - 6W$$

Calories

$$\text{or } 18.81C + 2900H - \frac{O + N}{8} + 25S - 6W$$

B.T.U. (B)

Thus, states Prof. Cobb, for English coals is correct to within 2 per cent.

(B). If again Ht represents the calorific value Cf represents the percentage of "fixed" carbon.

M represents the percentage of volatile matter.

and A is a fraction, for which a table is given below, then

$$Ht = (8150Cf + A.M.) \frac{1}{100} \text{ Calories.}$$

The fraction A was introduced by Goutal in an endeavour to prescribe for the different calorific values of the different volatiles from different classes of coal.

His classification is as follows:—

For Anthracites (*i.e.*, coals with from 2—15% vol.) A=1,300.

For Bituminous (*i.e.*, coals with from 15—30% vol.) A=10,000.

For Rich Gas Coal (*i.e.*, coals with from 30—35% vol.) A=9,500.

For Highly Volatile (*i.e.*, coals with from 35—40% vol.) A=9,000.

In addition to accepting the assumption that the volatiles can be divided into groups as regards calorific value, there is a further drawback, in that the formula does not take into consideration constituents other than the volatiles and fixed carbon. Thus, for example, there is sulphur, which varies widely with coals which are classified together in terms of their volatile constituents.

Generally, however, for English coals the formula is accurate to within 4 per cent.

2. *Moisture.*—The total moisture which may be removed from a coal substance or sample is the sum of four distinct quantities.

It is made up of:—

(a) "Superficial" moisture, present owing to the influence of local physical or weather conditions (*e.g.*, pit water on freshly mined coal) and which may be removed by air drying.

(b) "Associated" moisture, which may be looked upon as moisture occluded in the coal substance, and which may be removed by maintaining the coal substance at a temperature slightly higher than the boiling point of water (*say*, 105 deg. C.) for a few minutes.

(c) Water of composition or crystallisation, a great deal of which is removed at near 200 deg. C. when the first cellulosic decomposition of the coal substance occurs.

(d) Water of "Reaction" due to the combustion of the (hydrocarbon) hydrogen of the coal with oxygen when the coal is burnt.

"Associated" moisture is the item to which reference is made when speaking of the moisture content of a coal. But it will be seen that its determination may be made quite arbitrary unless a standard method is adopted by means of which the influence of superficial moisture is eliminated. The water of composition and water of reaction, jointly, are, of course, the factors which necessitate the discrimination between gross and nett calorific values.

Before discussing a standard method of determining the moisture content of a sample it may be of interest to quote a few results obtained by Sinnatt (*loc. cit.*)⁽⁶⁾ showing the influence of the hygrometric state of the atmosphere on exposed coal samples.

Coal	Type	Mesh.	Time	Moisture %	Degree of Humidity
Arley (Wigan)	Caking	1/30	9.46 a.m.	2.19	88.0%
do.	Bituminous	"	7.00 p.m.	2.08	73.0
do.	do.	1/180	9.46 a.m.	3.03	88.0
do.	do.	"	7.00 p.m.	2.56	73.0
Indian	Non Caking	1/30	10.40 a.m.	4.30	73.5%
do.	Bituminous	"	3.50 p.m.	4.75	79.5
do.	do.	1/200	10.40 a.m.	4.36	73.5
do.	do.	"	3.05 p.m.	4.76	79.5
Peat.	(English)	1/30	9.20 a.m.	14.40	68.8%
do.	do.	"	3.45 p.m.	13.75	63.6
do.	do.	1/200	9.20 a.m.	13.60	68.8
do.	do.	"	3.45 p.m.	13.04	63.6

The errors in the determination of moisture in coal, which are complicated by the change the coal substance itself undergoes when subjected to heat and exposed to the air, have been studied by several investigators, among them Hillebrand and Badger⁽⁷⁾ (Eighth Intern. Cong. Appl. Chem. 1912 at the American Bureau of Standards).

They concluded that the most nearly correct results may be obtained by drying in vacuo over concentrated sulphuric acid for a period of two days or more. They

compared the results obtained by this method with those obtained by the method recommended by the Committee of the American Chemical Society in 1899, and which prescribes that "1 gm. of the coal shall be dried in an open porcelain or platinum crucible at from 104 deg. to 107 deg. C. for one hour, and shall then be cooled in a dessicator and weighed covered," and showed that the latter gave values 9/10th as great as those obtained by the former. They showed, too, that if dry air was continuously circulated through the oven during the hour, that the results then agreed quite closely.

The method adopted by the U.S. Bureau of Mines⁽⁸⁾ is that of heating 1 gm. of coal for one hour at 105 deg. C. in a current of air previously dried and pre-heated. A mixture of glycerine and water is employed to obtain the required temperature, heating being carried out in a copper-jacketed oven.

The importance of this determination is that other figures, such as the volatile constituents, ultimate analysis, etc., in the analysis of coal, depend upon it.

Ash Determinations.—In carrying out this determination it might be stated that the temperature of combustion should not be excessive—between 700 and 750 deg. C. is regarded as best—as otherwise, not combustion alone, but also a certain amount of decomposition—akin to carbonisation—may take place, which might result in the deposition of a little "dense" carbon, or what may be more adequately described as a little condensed hydrocarbon, rich in carbon molecules (c.f. retort wall carbon). Should this be formed it is very difficult to completely burn away by oxidation. To provide against this eventuality it is always advisable to moisten the ash, after each determination, with a little alcohol, and then examine it for carbon particles.

For the sake, however, of a complete and accurate analysis of coal, the above is not in itself an adequate determination. This is due to the possibility of there being present a certain percentage of carbonates in the total non-combustible constituent of the coal substance, which would be decomposed at combustion temperatures with a liberation of CO₂. Directly this would result in a diminution in the estimation of the percentage of non-combustible matter

(6) F. S. Sinnatt—"Analysis of Coal."

(7) Hillebrand and Badger—Eighth Int. Cong. Appl. Chem., 1912

(8) U.S. Bureau of Mines Technical paper 8.

in coal. Indirectly, too, this same yield of CO_2 would be supplementary to the CO_2 assumed formed in the ultimate analysis determination by direct oxidation of the available carbon in the coal substance with the oxygen, and it would then tend to give an over-estimated value of the percentage of carbon in the sample.

The following abstract from the 1913 report of the U.S.A. Committee on Coal Analysis⁽⁹⁾ describes a method of conducting a more comprehensive determination on the ash percentage.

" Unless the coal is of a type known to be free from carbonate, the amount of carbon dioxide must be determined. A 5-grm. sample, recently boiled distilled water, and dilute hydrochloric acid are employed, making use of any convenient apparatus for collecting, absorbing and measuring accurately the carbon dioxide discharged from the coal. It is most convenient to obtain the factor as in the form of carbon.

" One grm. of coal, either freshly weighed, or that which has been used for the moisture determination, is ignited in a shallow capsule or porcelain crucible by placing directly in a muffle, maintained at a dull or cherry-red temperature between 700 and 750 deg. C., and retained at this temperature for 20 or 30 minutes, or until all of the carbon is burnt out.

" The capsule is cooled in a desiccator and weighed. In the absence of a muffle the desired temperature may be obtained by placing the capsule at first just above the tip of a luminous flame turned down to about 2in. or 3in. in height.

" After the larger part of the carbon is burned off in this manner the flame is increased so that the tip comes well into contact with the bottom of the capsule.

" For coals having carbon dioxide present in an amount to exceed 0.2 per cent., the ash, after cooling is moistened with a few drops of sulphuric acid (dilute 1 : 1) and again carefully brought up to 750 deg. C. and retained at that temperature for three to five minutes. The capsule is cooled in a desiccator and weighed. Three times the equivalent of the carbon present as carbon dioxide is subtracted from the ash weighed in order to restore the weight of calcium sulphate formed to the equivalent of calcium carbonate.

The composition of the ash becomes of importance where the danger of clinkers has to be taken into account. The fusion point of coal ash is, as a rule, between 1,000 deg. C. and 1,500 deg. C.—the latter would apply to ashes consisting mainly of silica and alumina, whereas the former would also have quantities of ferric oxide or lime, which would tend to mix with the silica and alumina to give a low eutectic point mixture.

The following are some typical analysis of coal ashes as quoted by J. T. Dunn (J.S.C.I., 1918, 37.161).⁽¹⁰⁾

Silica ..	..	25.90	40.40	45.40	47.10	51.80	51.89
Alumina ...	...	17.46	29.34	35.53	37.39	38.25	44.59
Ferric Oxide ...	...	16.86	15.21	12.57	11.14	5.64	0.98
Manganese Oxide	tr.	0.30	nil	0.40	tr.	nil	
Lime ...	...	22.80	4.61	3.54	0.82	0.45	0.38
Magnesia ...	...	3.22	1.96	1.23	0.65	0.74	0.38
Alkali ...	...	2.70	7.23	0.83	1.38	1.71	1.77
Titanium Oxide	...	0.74	0.95	0.90	1.12	1.41	0.15
Sulphuric Anhydride	...	8.91	—	—	—	—	—
Phosphoric Anhydride	...	1.55	—	—	—	—	—
Quicklime ...	...	5.95	—	—	—	—	—
Fusion tem. deg. C		1020	1230	1380	1460	1500	1500

The appearance of an ash may give a guide to its fusion point—thus reddishness can usually be attributed to the presence of ferric oxide which tends to lower the melting or fusion point. However, both alumina and silica are white, and so, too, is the lime, and whereas the former makes for a high fusion temperature, the latter tends to reduce it considerably. For this reason the only satisfactory method of arriving at the temperature is by a direct determination, and probably the most satisfactory method is that described by Prof. J. W. Cobb⁽¹¹⁾ and adopted with success in the Leeds University Fuel Laboratory. The method is the following:—

A considerable quantity of coal is burnt to obtain a liberal supply of ash. This is then ground to pass a mesh smaller than 1/100 to the inch. It is then mixed with the requisite quantity of water, with a little gelatine added, to form a stiffish paste, with sufficient adhesive properties to retain the form of a pyramid into which it is then

⁽⁹⁾ J. T. Dunn—J.S.C.I., 1918.

⁽¹⁰⁾ J.S.C.I. 1901, 23.11.

⁽¹¹⁾ U.S.A. Committee on Coal Analysis, 1913.

built up. The dimensions of the pyramid are in the ratio of

$$\frac{\text{base}}{\text{height}} = \frac{1}{3}$$

the size being made to suit the quantity of ash available. Preferably they should be made of the same height as the standard Seger cones against which they are compared. The pyramid has to be thoroughly dried (air dried) before being placed in the muffle.

The temperature at which the apex of the cone sinks to the base plane is assumed to be the temperature of fusion.

Volatile Matter and Coke.—The question of the estimation of the yield of volatile constituent matter by coals has been admirably and yet concisely described by Prof. Bone (*loc. cit.*), and for this reason a very full abstract has been made as follows:—

“ For commercial purposes coals are classified according to their suitability or otherwise for certain specific ends, *e.g.*, steam raising, furnace firing, gas making, the manufacture of dense metallurgical coke, low temperature distillation and the like. The usefulness of any given coal for a particular purpose depends largely upon its yield of combustible “ volatile ” matter, expelled when it is carbonised under certain specified conditions, and upon the resulting carbonaceous residue.

The following two standard tests may be cited by way of illustration:—

(a) *The American Test.*—In 1899 the American Chemical Society recommended the following method for the determination of the “ volatile combustible matter,” which has since been accorded international recognition. ⁽¹²⁾

“ Place 1 gram of fresh, undried, powdered coal in a platinum crucible weighing 20 to 30 grms. and having a tightly fitting cover. Heat over the full flame of a bunsen burner for seven minutes. The crucible should be supported on a platinum triangle with the bottom 6 to 8 cm. above the top of the burner. The flame should be fully 20 cm. high when burning free, and the determination should be made in a place free from draughts. The upper surface of the cover should burn clear, but the under surface should remain covered with carbon. To find the volatile combustible matter,

subtract the percentage moisture from the loss found here ” (p. 1122).

“ Practically the same test was adopted by the Canadian Coal Survey Chemists, except that it was carried out on the *dry* instead of the *undried*, as recorded above in the American procedure.”

“ It has always seemed to the author ” (continues Prof. Bone), “ that a test carried out under such conditions and on so small a quantity of coal in a platinum crucible is open to criticism both on account of the well-known intense ‘ catalytic ’ influence of hot platinum upon such thermal decompositions, and also because of the temperature conditions.

“ Also, it does not enable a sufficiently reliable judgment to be formed about the “ coking ” properties of the coal. Accordingly, after investigating the matter some years ago for himself the author ceased to employ the method in his laboratory, preferring the following, which, if carried out under “ standard ” conditions, has proved to be quite reliable within the limits required for commercial purposes.

“ (b) *Crucible Test.*—Twenty grams of the dried coal are weighed out (to the nearest centigram) into a No. 3 morgan fire-clay crucible, which has been just previously heated to redness in a muffle and then allowed to cool in a chamber containing an efficient drying agent. The crucible and its contents (lid on) are then put into a muffle furnace, the temperature of which has been raised to 900 deg. C., and kept constant at such a degree by a proper regulation of the gas supply. The charge of coal is thus “ carbonised,” the resultant inflammable matter escapes from the crucible, either through the hole in the lid or around the edges of it, and are ignited as they issue therefrom and mix with the air in the muffle. Heating is continuous for ten minutes after the evolution of the inflammable gases has entirely ceased. The crucible containing the carbonaceous residue is then withdrawn, and set to cool in the “ drying ” chamber, after which it is quickly re-weighed.

The test should always be carried out in duplicate if not in triplicate charges.

A subsequent examination of the carbonaceous residue enables a good idea to be formed of the “ coking ” properties of the coal, and as a *comparative test* of the pro-

⁽¹²⁾ *Journ. Amer. Chem. Soc.*, 1899.

perties of different coals it is most valuable.

The writer had recently the opportunity of observing the determinations and results of his former fellow-student, Mr. Lupton, of the Leeds University Fuel Department, carried out to investigate the influence of the material of the crucible and temperature on the yield of volatile matter. The results are in such remarkable agreement with the statement made by Prof. Bone that it is thought of value to quote them.

Under A are given the results obtained observing the standards of the American Chemical Society, and under B are those in accordance with Prof. Bone's method:—

A

Time of Heating.	Crucibles and Percentage of Volatiles.		
	Platinum.	Silica.	Porcelain.
7 mins.	42.7	40.0	39.5
10 ..	—	40.2	40.4

B.

Time of Heating.	Temp. deg. C.	Per cent. Volatiles.	
		Silica Crucible.	Porcelain Crucible.
7 mins	900 deg.	42.02	42.06
—	925	41.95	40.96
—	1,000	43.00	43.47

The conclusion arrived at by Lupton was that the American standard gave reliable and concordant results, but that accurate results could be obtained with silica and porcelain crucibles provided that the heating was carried out in a muffle maintained at a temperature of 900 deg. C.

Coke and Caking Factor—The residue left after expelling the volatile matter is generally termed the 'fixed' carbon and ash. It may or it may not exhibit the coherent features of coke, and its appearance supplies a very fair idea of the caking qualities of a coal. It does not, however, permit of a measurable estimation of the caking property.

Recently, Sinnatt & Grounds *J.S.C.I.*, 1920, Vol. XXXIX, No. 7, (12), have de-

veloped the method devised by Compiedon (*Comptes Rend.*, 1895), for measuring the caking value of a coal by heating a standard weight of coal with varying weights of inert matter (calais sand) in a platinum or porcelain crucible. The test was repeated until the maximum amount of inert matter which could be sustained by a coal, and still permit it to yield a coherent button of coke was found. A highly caking coal would of course sustain a high percentage of inert matter.

The ratio of the

$$\frac{\text{inert matter sustained}}{\text{coal used}}$$

by weight has been termed the "agglutination power," or the "coefficient of agglutination" of the coal.

The work of Sinnatt & Grounds includes a study of a standard measurement of the coherence of the ultimate coke, *i.e.*, the coke with its maximum amount of inert matter sustained—and they suggest that a 100 gram weight of a surface area, which is equal to that of a button of coke, should just succeed in crushing the button when placed on top of it.

For reasons which have to do with the rate of evolution of volatile matter, they conclude that it is preferable to use electrode carbon to sand or anthracite as the standard inert substance.

They also show that the degree of fineness of the inert matter is of very marked importance, and in fact have suggested an alternative method by means of which the degree of fineness of the inert matter, when added in a standard quantity, so as to destroy the coherence of the coke, may be accepted as a basis for comparing the caking properties of a coal.

To emphasise this point, they have constructed a series of curves showing the relation between the coefficient of agglutination against mesh of the inert matter. From these they conclude the following:—

"An examination of the curves leads to one point of importance, namely, that not only does the fundamental property of caking of different coals vary considerably, but the property is influenced by the degree of fineness of the inert substance until, when inert material finer than 190 mesh is taken, the caking property of the coal may be entirely destroyed by less than its own weight of inert matter. Attempts were made to determine the agglutinating value

with less than one unit of inert matter, but the results have not, up to the present, led to a satisfactory conclusion. There appears to be no reasonable objection to the conclusion that, if finer particles were used than those already experimented upon, the weight of the inert material required would be reduced. It is suggested that the most satisfactory manner of determining the agglutinating power of coal is to prepare a graph showing the relationship between the size of mesh of the inert matter used, and of the weight required to destroy the caking power of a unit weight of coal. This we have called the "Agglutination Curve"; it will be seen, however, that this determination is rather laborious, and as an alternative we suggest that the agglutinating powers of coal should be measured by the fineness of the inert matter required to destroy its caking properties.

"The manner of carrying out the test would be to mix one part of coal intimately with, we suggest, three parts of inert material, the size of particle of which should be varied until the coal will no longer yield a coherent button with the inert matter.

"The caking index would then be expressed in the degree of fineness of the inert matter, *e.g.*, one coal would be, say, 1/200 mesh, the next would be 1/75."

Sulphur.—There are various methods of estimating sulphur, which are generally described in detail in most text books, and of which the following may be considered as being of most universal use:—

1. The Eschka method.
2. The method of fusion of the coal sample with sodium peroxide in a suitable bomb.
3. Atkinson's method of fusion with sodium carbonate.

The percentage sulphur may also be determined, and the method is recommended as a convenient check provided the lining of the bomb is of an acid-resisting material, by utilising the products of combustion contained in the bomb calorimeter after a calorific value determination.

The bomb should be very thoroughly rinsed out with hot water and the solution so obtained precipitated as in the other methods with barium chloride.

Prof. A. H. White (*loc. cit.*) states that the tendency of this method is to give low results.

The barium sulphate precipitated by the barium chloride is in an exceedingly fine state, and takes a long time to settle. Prof. Parr (*Journ. Amer. Chem. Soc.*, 1904) ⁽¹⁴⁾ has utilised this feature for designing a photometric method of estimating the sulphur percentage.

Determination of Nitrogen in Coal.—The value of this determination is not apparent unless a full appreciation is given to the importance of the ammonia recovery in the destructing distillation of coal. "It is interesting," states Sinnatt, "to recall that in pre-war times much of the coal exported from Great Britain to the Continent contained a notably high percentage of nitrogen. In one particular year the average nitrogen content of the British coals purchased by one foreign nation was 1.9 per cent., which is far above the average percentage found in the ordinary coals consumed in the country. As a rule British coals contain about 1.5 per cent. of nitrogen, and these special coals were no doubt chosen by the foreign nation on account of the percentage of nitrogen present combined with the other virtues generally associated with British coals. It is doubtful whether the merchants selling the coal were aware of the high percentage of nitrogen in the coal and consequently of its enhanced value to the purchasers."

Until quite recently the method devised by Kjeldahl for measuring the nitrogen content of inorganic matter has been internationally accepted for the case of coal, and the Duma's method had been considered more as a means of checking the results obtained. From time to time, however, discrepancies have been noted, thus Fieldner & Taylor (*Tech. paper 64*, 1915, Bureau of Mines ⁽¹⁵⁾), after an exhaustive study, arrive at the conclusion that both potassium sulphate and mercury (or copper) sulphate must be introduced into the ordinary Kjeldahl method to ensure the complete conversion of the nitrogen in coal into ammonia. Shortly afterwards, however (*Z. Angew. Chem.*, 1915, 28, 481) ⁽¹⁶⁾, Simmersbach & Sommer, cast serious doubts

⁽¹⁴⁾ Prof. Parr—*Journ. Amer. Chem. Soc.*, 1904.

⁽¹⁵⁾ Fieldner and Taylor—U.S.A. Bureau of Mines, *Tech. Paper 64*.

⁽¹⁶⁾ Simmersbach and Sommer (*Z. Angew. Chem.*, 1915).

upon the accuracy of the Kjeldahl process, and state that a modification of Duma's method, invented by them, gives results which are up to 55% higher than those obtained by the Kjeldahl process.

In a more recent paper, Terres and others (good abstracts *J.S.C.I.*, 1919, 38, 399t) (¹⁷), describe results which also show that all

modifications of Kjeldahl's method yield low results owing to the evolution of free nitrogen during the process. They also show that Simmersbach's & Sommer's (*loc. cit.*) modification of Duma's method can be further improved by adding oxygen to improve oxidation.

The following are some of their typical results:—

Method.	Percentage of Nitrogen.	
	Ruhr Coal.	Anthracite.
Duma's method and special final oxidation	1.55	1.72
Kjeldahl + Potass. Sulphate + Mercury Oxide	1.35 (7 hrs.)	1.31 (11 hrs.)
Kjeldahl + Potass. Sulphate + Mercury Oxide + Copper Oxide	1.36 (8 hrs.)	1.38 (10 hrs.)

It has been suggested that as the low N_2 figures are due to the evolution of free nitrogen, they might be materially improved

by working at lower temperature. This is supported by the following table (*J.S.C.I.* abstracts (*loc. cit.*))

Method.	Temperature.	Percentage Volatile.	
		Suur.	Ruhr.
Kjeldahl	250 deg. C.	1.31	1.33
	275	1.21	1.26
	300	1.15 (44 hrs.)	1.20 (74 hrs.)
	325	1.00	1.07
Kjeldahl + HgO	200 deg. C.	1.35 (6½ hrs.)	1.31 (7½ hrs.)
Dumas with after oxidation	—	1.73	1.55

Further confirmation of this point has been communicated to the author by his former fellow-student, Mr. A. Greenwood,

of the Leeds University Fuel Department.

His results were as follows:—

Method.	Temperature.	Time.	Per cent. Nitrogen.
Ordinary Kjeldahl ...	250 deg. C.	49 hours.	1.71
	300	12	1.60
	325	12	1.51
Kjeldahl + HgO ...	about 300 deg. C.	5 hours	1.59
Dumas ...	—	—	1.72

It is well, however, in reviewing a method for the determination of nitrogen to recall the fact that the importance of getting the total percentage of nitrogen present in the coal is insignificant as compared with that of obtaining information of the percentage of the nitrogen of a coal which is available for recovery as ammonia.

Usually at least 50 per cent. of the total nitrogen of a coal is in all modern recovery processes left in the coke or ash, and furthermore it is only a portion of the remainder—for some does escape as free nitrogen—that is fixed as ammonia.

Under these circumstances the author is of the opinion that the Kjeldahl method should be examined from the point of view of its ability to classify the ammonia yielding percentages of nitrogen of coals, rather than, as in the present cases, the total percentages of nitrogen.

Ultimate Analysis of Coal.—In general principles the process employed for coals resembles that advocated in all text books on organic chemistry for the estimation of the percentage of carbon and hydrogen in organic substances.

In detail, however, there are important differences for coals, which must be observed if reliability is to be ensured. These have mainly to deal with the inclusion of chemicals which are particularly suited to meet the volatiles evolved when coal is combusted, and with details of manipulation.

Simmatt, in his bulletin on "Coal Analysis," describes a reliable method which closely resembles the one in use in the Leeds University Fuel Department, and with which reliable results could be obtained after experience had been gained in generally conducting the analysis, and particularly in regard to the best regulation of the temperatures.

The usual type of combustion furnace used in organic analysis is employed, the tube being of highly refractory glass, about 13 mm. in diameter.

The customary reagents for substances containing sulphur and nitrogen are included in the tube, *i.e.*, lead chromate and a bright copper spiral at the outlet of the tube.

3. CLASSIFICATION OF COAL.

Up to the present all attempts at a classification, whether based on geological occurrence or percentage of composition, have had the sole aim of grading the various types of coal in accordance with their utility in various technical and commercial processes, and as such they have in general been of great value.

Efforts are now being made to arrive at a system, which shall be more scientifically exact, and whereby the chemical structure of coal, and the probability of isomerism occurring will be taken into account. It is probable that the divergence of certain coals from the aforementioned systems of classification can be traced to isomerism, which is prevalent throughout organic chemistry. Sufficient data, however, is still wanting for this more comprehensive and scientific classification, and faith has still to be pinned to the older methods, or such modifications of them as have shown themselves to exercise a more defined limit.

It is intended to review briefly the prevailing methods and to introduce the modifications which authorities have judged to be an improvement. In the first place it has been judged essential that all classifications should be made on a dry and ashless basis, or, in other words, on the pure coal substance.

The earliest attempt was based on the ultimate analysis, and Regnault, who was the pioneer in this work, showed that, within narrow limits, a suitable classification, principally bearing on the carbon and oxygen contents, could generally be made. His method was modernised by the French metallurgist Gruner, and has further been modernised and brought more into conformation with English coals by Prof. Bone and Prof. Brame, both of whose suggestions are appended for comparison:—

1. Prof. Bone (*loc. cit.*) Regnault-Grimmer classification for English coals.
(Dry and ashless basis.)

Groups	Class	Chief Use	Percentage Composition.			Volatiles at 900 deg. C.	Fixed Carbon.	Character of Carbonaceous Residue.
			Carbon	Hydrogen.	O + N + S.			
A Lignite	Non-caking		60 to 75	abt. 5.0	20 to 35	above 15	below 55	Non-coherent.
	1 Non-caking Long flame	Furnace Reverberatory	75 to 80	4.5—5.5	15 to 20	40 to 45	55 to 60	Non-coherent.
B Bituminous	2 Caking Long flame	Gas making	80 to 85	abt. 5.6	10 to 15	32 to 40	60 to 68	Very porous coke.
	3 Hard caking	Coke manufacture	81 to 89	5.0—5.6	5.5—10.0	26 to 32	68 to 74	Dense coke.
B C Semi-bituminous.	4 Hard caking Short flame	Coke manufacture & steam raising.	88 to 90	4.5—5.5	5.5—6.5	18 to 26	74 to 82	Very dense coke.
	Non-caking Short flame	Steam raising.	90 to 92	4.0—4.5	4.0—5.5	15 to 20	80 to 85	Weakly caking or non-coherent.
C Anthracitic or Anthracites	Non-caking Anthracitic.	Steam raising.				8 to 15	85 to 92	
	Non-caking Anthracites.	Domestic and central heating.	92 to 94	3.0—4.0	3.0—4.5	below 8	above 92	Pulverulent.

Prof. Brame-Gruner classification modified for coals of Great Britain.

No. of Class.	Genus.	Class.	Per cent. Composition.			% Volatiles.	% Fixed Carbon.
			Carbon.	Hydrogen.	Oxygen.		
I.	Lignites.	Lignitions.	75 to 80	4.8 to 5.5	12—20	35 to 47	65 to 53
II.		Ligno Bituminous.	78 to 84	4.5 to 6	8—13.5	35 to 45	65 to 55
III.	Bituminous	Non-caking long flame.	82 to 86	5 to 6	6—12	30 to 40	70 to 60
IV.		Partly caking long flame.	82 to 86	4.5 to 5.5	5—9	30 to 40	70 to 60
V.		Caking short flame.	85 to 89	4.5 to 5.5	4—7.5	20 to 30	80 to 70
VI.	Semi-bituminous.	————	89 to 92	4 to 5	2—4.5	12 to 20	87 to 80
VII.	Semi-anthracites.	————	91 to 93	3 to 4.5	3—5.0	8 to 13	92 to 87
VIII.	Anthracites.	————	over 92.5	below 4.0	below 3.0	below 8	above 92

A comparison of the above tables will indicate the extent to which the Regnault-Gruner system will permit of limiting the classification.

A new departure in this matter was made by Mr. C. A. Seyler (Proc. S. Wales Inst. Engineering XXI., p. 83, and XXII., p. 112) ⁽¹⁵⁾, as a result of a very exhaustive examination of the Welsh coals, which include a very wide range from bituminous, semi-bituminous, anthracitic and pure anthracites. He divides coals into five principle genera according to their hydrogen content; each genus is then sub-divided into a number of species according to the percentage of carbon. The classification thus really depends on two factors, namely, in the first place upon the oxygen content, and in the second upon a C:H ratio.

Drs. A. Strahan and W. Pollard, of the Geological Survey of England and Wales, in their "Memoir upon the Coals of South Wales" (2nd edition, 1915) ⁽¹⁶⁾, adopted Seyler's general plan and nomenclature as one of the best so far available for the purpose of scientific classification, and defined the observed limits for the five principal genera as follows:—

Group	Genus	Percentage Hydrogen	C:H ratio
I	Anthracitic	Under 4.0	Over 22
II	Carbonaceous	4.0 to 4.5	20.2 to 23.5
III	Semi-bituminous	4.5 to 5.0	16.6 to 20.4
IV	Bituminous	5.0 to 5.5	14.6 to 18.2
V	Par-bituminous	Over 5.5	12.2 to 14.7

Also the United States Geological Survey, independently of Mr. Seyler's previous work, and after considering several other possible schemes, finally adopted the following classification, which is also based upon the C:H ratio in the pure coal substance. (Report on coal testing plant of the U.S. Geological Survey, Vol. 1, 1906, pp. 156, 73) ⁽¹⁷⁾.

⁽¹⁵⁾ C. A. Seyler—Proc. S. Wales Inst. Engg. XXI and XXII.

⁽¹⁶⁾ Drs. Strahan and Pollard—"Memoir upon the Coals of S. Wales."

⁽¹⁷⁾ Report on coal testing plant of U.S.A. Geological Survey, 1906.

Group.	Description.	Ratio C : H.
A	Graphite.	—
B	Anthracite.	? to 30
C	"	? 30 to 26
D	Semi-anthracite.	? 26 to 23
E	Semi-bituminous.	? 23 to 20
F	Bituminous.	20 to 17
G	"	17 to 14.4
H	"	14.4 to 12.5
I	"	12.5 to 11.2
J	Lignitic.	11.2 to 9.3?
K	Peat.	9.3 to ?
L	Wood.	to 7.2

It would thus appear that a considerable weight of opinion is in favour of adopting the C:H ratio for the pure coal substance as the most satisfactory basis of classification at present available for this purpose.

In concluding, it appears to the author that, although as shown by Garrick Anderson as early as 1898 (*J.S.C.I.*, p. 1013), that coals of different strata and geological age are found with the same elemental composition, and further that cases have often been pointed out where coals which closely resemble each other in elemental composition possess very different properties, yet some modified form of the Regnault-Gruner and Seyler classifications could be drawn up for particular coalfields that could be applied in grading the various coals.

APPENDIX.

1. The following abstract from the Board of Trade leaflet on "Coal Sampling" enables a comparison to be made with the matter already abstracted from English and American authorities:—

COAL SAMPLING FOR ANALYSIS

"Hints on the best method of obtaining thoroughly representative samples."

1. *General*.—The importance of ascertaining the calorific value of fuel used in any particular works cannot be over-estimated. It is quite impossible to control intelligently the thermal efficiency of any plant unless means are taken to establish the calorific value of the coal used. Far too little attention has hitherto been paid to the question of sampling, whereas, however carefully the analysis is taken, the final result will be of little value unless a thoroughly representative sample has first been obtained. When

one considers that the heat value of a particular consignment of fuel is ultimately determined on about one ten-thousandth part of a 20lb. sample, it will be appreciated how easily an error of 1,000 to 2,000 B.Th.U.'s can be made if the sampling is not carefully attended to.

"As indicating the importance of the necessity for careful sampling the following instance may be given:—

"A slack coal recently received from a Midland colliery gave no indication from appearance of being anything abnormal. On separating the small from the large, however, the small was found to contain 10 per cent. of ash, whereas the large contained 40 per cent. of ash. What would be the worth of an analysis as representing the heap from which the sample had been taken if the proportion of large and small received in the laboratory had not been representative of the large and small in the heap? Let us assume that in the heap from which the sample was taken the percentage of small was 25 per cent. This would give a total ash content of 32.5 per cent., namely, 25 per cent. with 10 per cent. of ash and 75 per cent. with 40 per cent. of ash. Now, if the sample sent to the laboratory contains 75 per cent. of small the total ash contents of the sample would be only 17.5 per cent., namely, 75 per cent. at 10 per cent. and 25 per cent. at 40 per cent. It will be seen at once that the calorific value as disclosed by the laboratory would vary tremendously in the two samples referred to."

2. *How to Take Preliminary Samples.*— "To obtain as nearly a representative sample of the bulk as possible the following procedure should be adopted:—

"(a) Large Screened Coal.—The sampling of large screened coal is perhaps the most difficult with which the fuel analyst has to contend. The consignment may contain anything from 5in. or 6in. cube up to 12in., 15in., or even larger pieces. The best plan is by carefully inspecting a consignment of, say, 10 tons, to pick out fairly representative pieces to the extent of about 10 per cent. These pieces should then be broken, and again, by a further selection, about 10 per cent. separated from the bulk. This smaller sample should be further broken and thoroughly mixed, after which a final sample of about 10lbs. can be selected for the laboratory.

"(b) Large unscreened coal (through and through) Separate about half a ton into

two heaps, one containing the large and the other small, in order to ascertain their respective percentage by weight. If, for instance, the coal contains 50 per cent. of large and 50 per cent. of slack, a proportion of the larger pieces should be dealt with as described under the heading of "Large Screened Coal," and the slack dealt with in a similar manner to that described below.

"(c) Graded Coal (Nuts, Beans, Peas, etc.).—This is the simplest class of coal from which to obtain representative samples, as a few shovelfuls from various parts of the main heap are all that is usually necessary.

"(d) Slack Coal.—To obtain a really reliable sample of slack coal from a given heap it is advisable to start with a fairly large quantity. Where trucks or carts are being continually received and unloaded three or four or more shovelfuls of the fuel should be taken from different parts of each load and thrown on to a common heap. When the testing sample has to be taken this heap should be carefully trimmed round at the edges, the coal so trimmed being thrown into the centre so as to form a rough cone. This cone should then be flattened by means of a straight board twisted across the top of the heap until it becomes a flat disc of, say, 2ft. thick. This should then be divided into four, or what is known as 'quartering,' and the two opposite segments removed. The remainder should then be re-mixed and treated as before to obtain a final sample of about 20lbs. weight for slacks of 1in. and under, or 40lbs. weight for rougher slacks."

3. *Weight of Samples for Laboratory Tests.*—"The final sample forwarded to the laboratory should never be less than 10lbs. in weight, and in dealing with difficult fuels—amongst which are included nearly all slacks—it is desirable to increase this up to 20lbs. or even 40lbs."

4. *How to Deal with Laboratory Samples.*

"We will describe the best method to be adopted with a difficult sample of slack fuel at some length. With crushed coal and more consistent grades experience will show that some of the stages may be omitted, but it is better to begin with too much attention to detail rather than too little.

"Before attempting to reduce the sample as submitted to the laboratory to suitable dimensions for actual test, it is essential that the surface moisture should be taken

from it. This can best be done by recording the weight of the whole sample, which should then be left on a large tray spread out in a very thin layer for, say, 48 hours. This air drying is necessary for two reasons: Firstly, the total moisture cannot otherwise be correctly ascertained, as the coal will be losing moisture during sampling; and, secondly, it is otherwise impossible to get a good mixture, as the small damp coal and soft shale will cling together and not mix with the dryer coal when it is ground.

"It is wrong to rob the laboratory sample of a part for separate moisture determination, as is frequently done, inasmuch as this would have to be done with little or no crushing of the large coal, and would not only be unrepresentative of the remaining moisture content, but may also be robbing the remainder of an undue portion of either clean coal or shale.

"After being exposed, as suggested above, for 48 hours in the room in which the further sampling is to be carried out, the coal will be at equilibrium with the atmosphere, and in this condition can be safely ground and mixed without either losing or gaining moisture."

Grading the Sample.—"It is often very difficult to thoroughly mix a sample of ground coal weighing 20lbs. It may be thought that if the whole sample is ground and mixed that no better way can be adopted. This is not so. If such a scheme is adopted it will be found that after several hours' stirring and mixing has taken place, streaks of varying colour, indicating varying quality, will still remain and it is quite impossible to take the two ground calorimeter samples from any part of the 20lb. heap and be sure that they fairly represent the bulk."

The following will be found a very satisfactory method of overcoming this difficulty—

"Separate the 20lb. sample by means of sieves, carefully noting the weights and proportions of each. The following is an example of the method—

	Proportion per cent
(a) Over $\frac{1}{4}$ in. and under 2in. in size, say, 5lbs.	25
(b) Over $\frac{1}{8}$ in. and under $\frac{1}{4}$ in. in size, say, 3lbs.	15
(c) Over $\frac{1}{16}$ in. and under $\frac{1}{8}$ in. in size, say, 4 lbs.	20
(d) Under $\frac{1}{16}$ in. in size, say, 8lbs.	40
20lbs.	100

"It will be evident that one should not expect to find the heat value of all these grades similar. This will particularly apply when comparing the $\frac{3}{4}$ in. to 2in. sample with the under $\frac{1}{4}$ in. sample. In some cases the fine coal contains more heat units than the larger coal, but in the majority of cases the fine contains a large amount of dirt, and consequently is of lower value.

"These heaps can be now further reduced, dealing first with the very fine. After thoroughly mixing, carefully weigh out 25 per cent. and place in a labelled covered tin. The remaining heaps of the larger grades should then each in turn be thoroughly ground and mixed. This can best be done by means of 'Spong No. 5' coffee mill. Each grade should be treated separately, and, after grinding, passed through the $\frac{1}{4}$ in. mesh sieve. Twenty-five per cent. by weight of each should then be taken and placed in a separate labelled tin in the same way as the fine coal.

"We should now have four tins containing a total weight of 5lbs. of coal, and are sure, so far, of having a proportionate amount of the better and inferior (large and small coal. This we could not have been so sure of had we ground the whole 20lbs., mixed it, and then taken out 5lbs.

Final Samples.—"The next step is a still further reduction of the sample for analysis. Taking the first tin:—This should all be ground to pass through a sieve having 30 meshes to the inch, thoroughly mixed, and 25 per cent. of the total taken and placed in a covered tin. The other tins should then be treated in a similar manner separately, 25 per cent. of each, after having been passed through the 30 mesh to the inch sieve, to be added to the first sample. We are now certain of having one-sixteenth of the various grades of coal which were delivered to the laboratory in the original sample.

"The next step is to thoroughly mix this remaining sample, and after taking a fair quantity of this for moisture determination—to be added to the amount already determined by air drying—take about a quarter of it, and with the use of a pestle and mortar pass the whole of this quarter through a sieve having 60 meshes to the inch. As with some coals, a loss of about 0.5 per cent. occurs through dealing with small quantities at a time with the pestle and mortar in passing this sample through 1/60in. mesh it is advisable to determine the moisture content on part of the sample

before passing through the 1.60in. mesh. In any case this will be a check with moisture determination in the final sample.

" Too much importance cannot be attached to seeing that the whole of this final sample passes through the sieve, for the more friable particles—which usually consist of clean coal—will more readily break up and pass through the fine meshes, leaving the harder particles—generally slack—behind; and if these are not broken to the same fineness and mixed with the remainder, the sample will be spoilt.

" After thoroughly mixing this very fine coal on a sheet of glazed paper, we can take our samples, which must, of course, first be dried, for the calorimeter test and analysis, from any part of the heap, and if the difference obtained from such samples exceeds 0.2 per cent. for the former or 0.1 per cent. for the latter, something must be wrong with the operation of determining the heat value or analysis, and the error should be looked for in this direction.

" Although this operation of sampling may suggest loss of moisture during the whole period, on actual tests this loss has not exceeded 0.5 per cent. even on a coal containing as much as 12 per cent. of hygroscopic moisture, and the smaller the quantity of hygroscopic moisture contained in a coal, the less chance there is of losing any moisture by this method. The maximum loss of 0.5 per cent. on a coal of 12,000 B.Th.U.'s amounts to 60 B.Th.U.'s, which is negligible when compared with the much greater error which can be introduced by incorrect sampling. Further, one has to remember that there will frequently be a loss of moisture during the original sampling before the coal reaches the laboratory."

2. *The use of Solvents in Estimating the Coking Quality of a Coal.*—Broadly speaking, it has been established that the coal substance consists of the following:—

1. A cellulosic constituent,
2. A resinic constituent, and
3. A nitrogenous constituent,

and in every process in which coal is utilised each plays its own definite role.

In the present instance it is intended to confine attention to the resinic constituent, which it has been definitely shown is of vital importance in deciding the caking or non-caking character of a coal.

In the first place it was necessary to devise a method which would permit of the extraction of the resinic constituent without, in the process, destroying or modifying its character. The only feasible method was by employing solvents. Solvents which have been shown to exert an extracting influence are the following:—

Benzene (Fischer & Gludd)⁽²¹⁾, (Pictet & Ramsdameyer)⁽²²⁾.

Chloroform (Smythe).

Pyridine (Clarke & Wheeler)⁽²³⁾, (Graham & Winnell)⁽²⁴⁾.

A convenient chart can be drawn up as derived by Prof. Bone (*loc. cit.*), which enables a rapid survey to be made of the influence and character of the resinic constituent. (See page 19.)

An examination of the quantity of oxygen appearing in the products will show it to be 1.27 times as great as the oxygen present in the original parent coal, thus demonstrating that the process was not one of pure solution.

The more recent work of Graham and Winnell, in the Doncaster Coal Association Research Laboratory, shows that the errors apparent in Clarke and Wheeler's results are probably due to lack of precaution in manipulating the pyridine, which they have shown must be in a nascent state, and must be used out of contact with air from which it absorbs oxygen.

This, however, does not in any way detract from the value of the work as demonstrating the influence of the resinic constituent on the coking qualities of the coal.

Another interesting feature of Graham & Winnell's work was the demonstration that if oxygen was passed over the insoluble residue (cellulosic constituent) spontaneous ignition took place. Thus they exploded the older impression that it was the sulphur in the pyrites that led to spontaneous ignition, and at times explosions in mines.

(21) Fischer and Gludd—*Ber. Dent. Chem. Ges.*, 1916.

(22) Pictet and Ramsdameyer, see *Gas World*, 1917.

(23) Clarke and Wheeler—*Ibid.*, 1913. See also Burgess and Wheeler, *Journ. Chem. Soc.*, 1911.

(24) Graham and Winnell—*Proc. Inst. Min. Eng.*, 1921.

Parent Coal.

C=82.92%

H= 5.58

N= 1.35

S= 1.70

O= 8.45

Volatiles

36.73

Insoluble 80%
in Pyridine.

C=80.81%

H= 5.23

N= 2.14

S= 1.41

O=10.41

Volatiles

34.96

Insoluble in
Chloroform 16%.

C=77.32%

H= 5.14

N= 2.07

S= 1.21

O=14.2

Volatiles

31.88

Soluble

20%

Soluble in
Chloroform 4%

C=85.33%

H= 7.08

N= 1.71

S= 1.32

O= 4.56

Volatiles

77.33

An examination of this residue showed that a certain amount of destructive distillation took place at low temperatures, but the substance itself did not melt or coke together as the original coal did.

On heating to high temperatures large quantities of gas, high in H_2 %, were evolved. Hydrogen was particularly pronounced between 750 and 800 deg. C.

This behaved very much as did the above insoluble residue. It did not coke or melt and yielded large quantities of H_2 —but no hydrocarbons, showing that the extraction with pyridine was an over-extraction which was corrected by the additional use of chloroform.

This portion melted quite easily like tar itself and began to decompose and distil over on heating at quite low temperatures, and yielded large volumes of heavy saturated and unsaturated hydrocarbons. It was resinic in character and appearance, and evidently is responsible for the caking character of the coal.

Notices and Abstracts of Articles and Papers.

ANALYSIS OF FAR EAST RAND ORE

By F. W. WATSON

(Printed in Journal, May, 1921.)

CORRENDUM

Page 198, Nickel Sulphide (NiS), 0.336, should read Nickel Sulphide (NiS), 0.036

CHEMISTRY

DETERMINING THE PERCENTAGE OF BOILER FEED WATER.—Oxygen in solution in feed water.—Atmospheric air dissolves in water almost instantaneously up to the point of saturation for the

particular temperature and pressure. At ordinary temperatures and pressures, 18 cc. of pure nitrogen and 35 cc. of pure oxygen form saturated solutions with one litre of water. The quantities of each dissolved from air are therefore:

Nitrogen: $0.8 \times 18 = 14.4$ cc.

Oxygen: $0.2 \times 35 = 7.0$ cc.

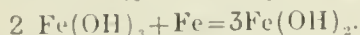
The air dissolved in water will therefore contain roughly 33 per cent. of oxygen, and be twice as rich in this gas as atmospheric air.

Method of Oxygen Determination.—Max Muller's method with modifications is used. Manganese sulphate is dissolved in the sample to be tested, and, by the addition of sodium hydroxide, the hydrated manganese monoxide is precipitated, thus absorbing the oxygen contained in the water, transforming it into an oxy-salt and the dioxide, this is treated with HCl reacting on the oxides of manganese, giving off a quantity of chlorine equivalent to the quantity of oxygen absorbed. The freed sodium chloride reacts on KI, freeing the equivalent of iodine. Titration by hyposulphite of soda gives the quantity of iodine, and enables the equivalent of oxygen to be determined.

When the sulphate of manganese is dissolved, 5 cc. of NaOH is added and shaken. A dirty white precipitate is formed, turning more or less yellow, according to the quantity of oxygen content in the water. At the end of a quarter of an hour the absorption of oxygen is complete. Next 2 cc. of solution of 50 per cent. KI, free from iodate is added, and then 20 cc. concentrated HCl. Shake until precipitate is dissolved. The iodine is then determined.

The method is simple, rapid and exact, and is delicate, with only traces of oxygen present.

Removal of Oxygen.—Several physical methods are mentioned such as the spraying into vacuum and boiling. Kestner describes his chemical method in which he reduces practically all the oxygen by means of steel turnings containing up to 0.8% of manganese. He has discovered that manganese acts as a catalyser in hastening the oxidation of the iron or transferring the oxygen from the solution to the steel. To avoid the slowing of the oxidising process by the rust deposit on the iron, he has found that the red iron rust, after a day's standing in oxygen free water, becomes an oxide of a greenish black colour. This transformation is due to the reduction of the ferric hydroxide by the metallic iron, ferrous oxide being formed by the following reaction:



The reaction takes place in the presence of iron and absence of oxygen. The process therefore becomes recuperative. In practice a column of turnings of sufficient quantity for half only to be in action is used. The water is passed through alternately upward and downward, the first half acting as a reducer of oxygen in solution, and the second half as regenerative of the ferrous oxide. The consumption of iron turnings varies according to the oxygen content of the water, and is small; it varies from one to three grammes per cubic metre of water.

(Abstract of the portion dealing with de-aeration of water or solutions in a paper entitled, "De-gassing and Purification of Boiler Feed Water," by Paul Kestner, at a joint meeting of the Institution of Mechanical Engineers with the Society of Chemical Industry, 4th March, 1921.) (F. W.)

RAPID METHOD FOR THE ANALYSIS OF MONEL METAL. The accumulation of large volumes of filtrates, necessitating considerable evaporation, is avoided by using separate samples for the determination of the different constituent elements. Carbon is determined by direct combustion in a Fleming apparatus (*Iron Age*, Jan. 1, 1914). For the estimation of silica, 1 gram of Monel metal is dissolved in nitric acid and the solution evaporated to about 7 cc., diluted to 50 cc., and filtered. Dehydration of silica is not considered essential for most purposes. Copper is deposited by electrolysis from the filtrate made up to 150 cc. and acidified with 5 cc. of sulphuric acid (1:1), using a current of 1.5 amps. for 2 hours. A separate solution of 1 gram of borings in nitric acid is used for the precipitation of iron and aluminum hydroxides, which are redissolved in hydrochloric acid and the iron reprecipitated by means of potassium hydroxide. Iron is estimated by reducing the solution of the precipitate in hydrochloric acid by

means of stannous chloride and titrating with permanganate, using a "preventive solution" containing 160 grms. of manganous sulphate, 330 cc. of syrupy phosphoric acid, and 320 cc. of concentrated sulphuric acid in 1750 cc. of water. Manganese is determined by the bismuthate method, and nickel by means of dimethylglyoxime, care being taken to obtain the proper degree of alkalinity in the latter method."—P. COVITZ, *Chem. and Met. Eng.*, 1920, 22, 31-32.—*Journ. Soc. Chem. Ind.*, Feb. 28, 1920, p. 157A.

METALLURGY.

ELECTRO-DEPOSITION OF GOLD AND SILVER FROM CYANIDE SOLUTIONS.—"The paper, which embodies the results of twenty years' investigations on the electro-deposition of gold and silver from dilute cyanide solutions such as are obtained in the leaching of ores, contains a review of all the methods that have been proposed, more especially those which the author himself has worked out. Clear solutions and rapid circulation are necessary for good results. A large cathode area and an excess of potassium cyanide above that required to form the double cyanides are necessary for rapid and complete precipitation, and, if the voltage is kept low and the circulation rapid, a considerable amount of cyanide is regenerated. The current should be stopped at the point at which the amperage becomes constant. The use of pervious electrodes (fragments of carbon packed in boxes) both as anodes and cathodes has been adopted. A complete description of the construction and working of a model plant is given. The cell consists of an oblong wooden box containing a simple pervious cathode at one end and a simple pervious anode at the other. The intervening space is filled up with a series of compound pervious electrodes $\frac{1}{4}$ in. apart with a potential of 3.5 volts between each. The electrodes are all made up of "Excelsior" charcoal (carbonised "Excelsior fibre") packed in wooden frames, both sides of which are covered with cheesecloth. The solution is circulated through the box by means of a small centrifugal pump; the speed of circulation is determined to a large extent by the current gap, a $\frac{1}{4}$ in. gap giving three times the capacity that a $\frac{1}{2}$ in. gap gives. In the former case, for example, for a 96% precipitation a maximum capacity of 144 tons per 25 hours for a 1-ton box was obtained."—S. B. CHRISTY, U.S. Bureau of Mines, Bull 150, 1919, p. 171.—*Jour. Soc. Chem. Ind.*, 15th May, 1920, p. 337A. (J. A. W.)

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AUGUST, 1921.

No. 2.

THE KATA-THERMOMETER AND ITS PRACTICAL USES IN MINING.

By H J IRELAND, M.B.E., B.Sc.,
A.M.I.C.E.

(Printed in Journal, November, 1920.)

ADDENDUM.

In connection with Dr. Leonard Hill's Kata-thermometer, the formulæ giving the relation of cooling-power to wind velocity have been recently revised by careful and exhaustive tests carried out in the wind tunnels of the National Physical Laboratory, and the results have just come to hand.

The formulæ previously given were based chiefly on tests carried out at the East London College, low velocities were not investigated, and, unfortunately, some error crept in, in those velocities which were measured.

The results of the revised tests carried out in the 4ft. and 7ft. wind tunnels of the N.P.L. agree with results obtained at Oxford by rotating arm at low velocities, and agree also with later tests at the East London College; these results can now therefore be accepted with confidence. The new formulæ explain some anomalies between velocities computed from kata readings and those obtained by anemometer, which were brought to our notice some time ago.

The wet kata formulæ are now given in terms of the wet bulb temperature instead of vapour pressure, which is a considerable advantage, as it saves the time and trouble of looking up tables of vapour pressure.

Dry kata formula

Let H = cooling power in milliwatts per sq. cm. per sec.
 t = air temperature in degrees Cent.
 $\theta = (97.7 - t) - V$ = velocity in metres per sec.

Then for wind velocities greater than 1 metre per sec., i.e., for values of H/θ greater than 0.6.

$H = (0.13 + 0.47 \sqrt{V})\theta$ (i.)

For wind velocities less than 1 metre per sec.

$H = (0.2 + 0.4 \sqrt{V})\theta$ (ii.)

Formulae (i.) and (ii.) expressed in feet per minute and degrees Fahrenheit become—

$H = (0.072 + 0.019 \sqrt{V})\theta$ (iii.)

and

$H = (0.11 + 0.016 \sqrt{V})\theta$ (iv.)

where $\theta = (97.7 - t)$, t being the air temperature in degrees Fahr.

Wet kata formulae:

Let H' = wet cooling power in m-cal. per sq. cm. per sec.

t' = wet bulb temperature of air in degrees Cent.

$\theta' = (36.5 - t') V$ = velocity in metres per sec.

For velocities greater than 1 metre per sec.

$H' = (0.10 + 1.10 \sqrt{V})\theta'$ (v.)

For velocities less than 1 metre per sec.

$H' = (0.35 + 0.85 \sqrt{V})\theta'$ (vi.)

Formulae (v.) and (vi.) expressed in feet per minute and degrees Fahrenheit become—

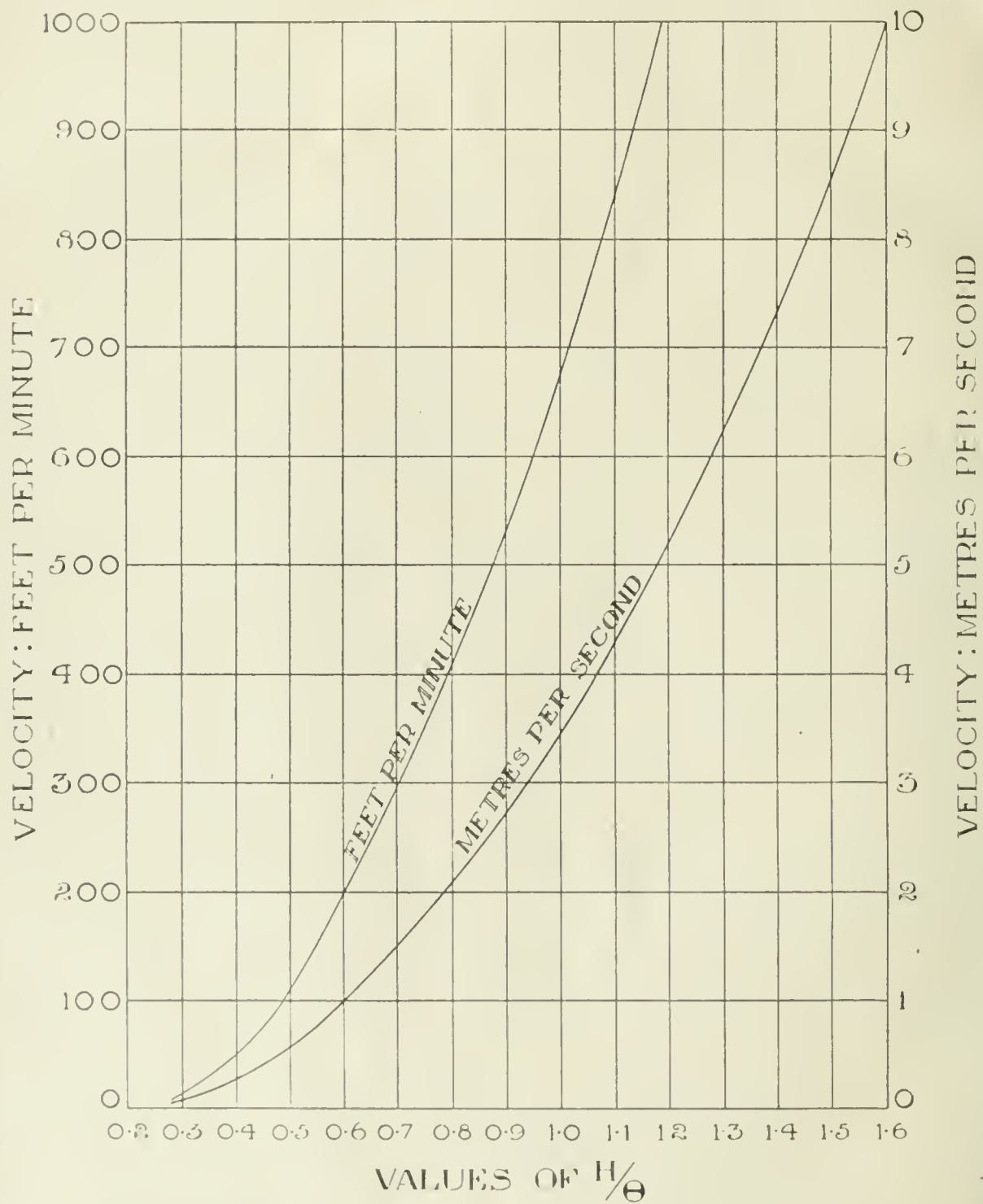
$H' = (0.056 + 0.11 \sqrt{V})\theta'$ (vii.)

and

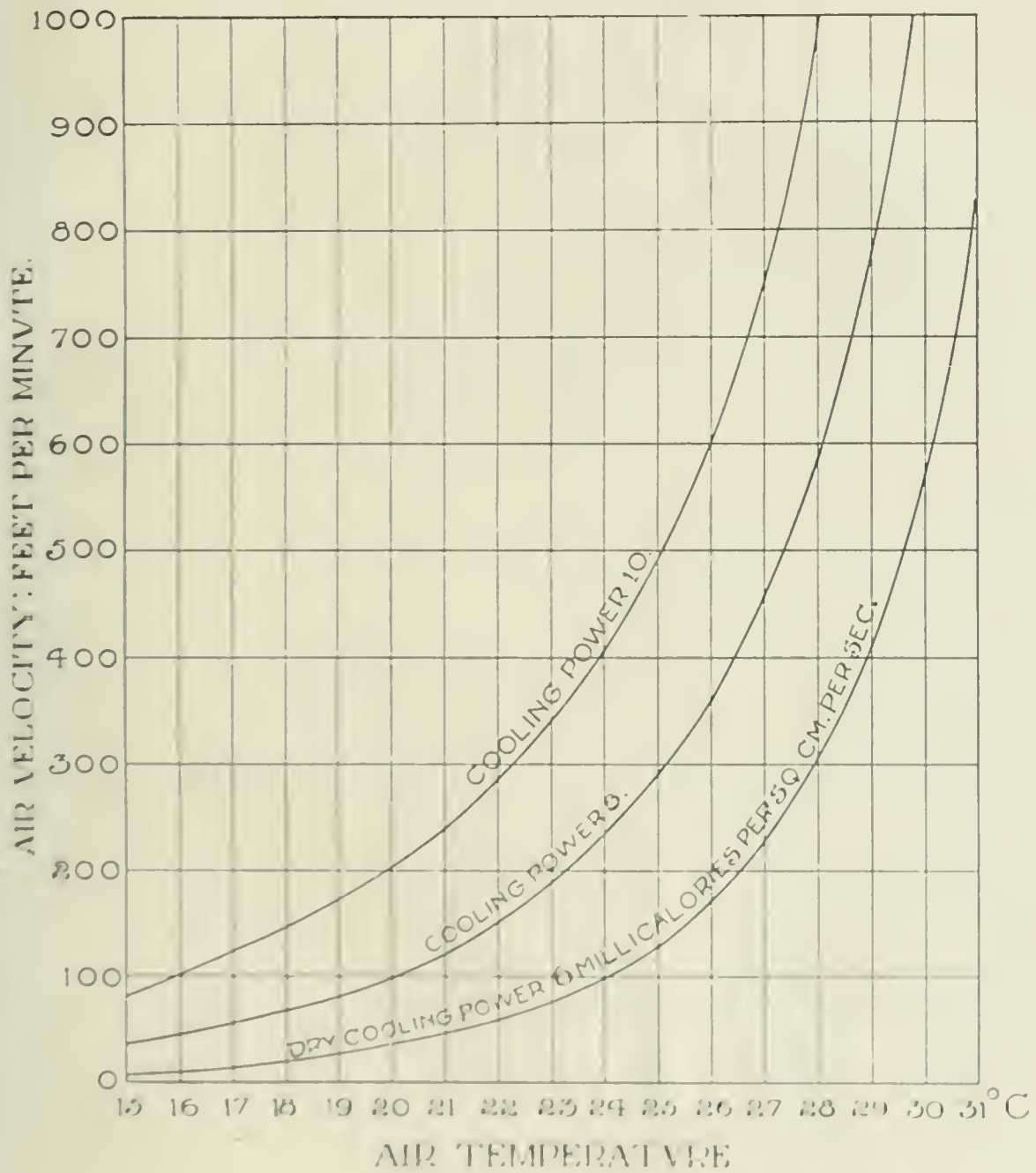
$H' = (0.19 + 0.082 \sqrt{V})\theta'$ (viii.)

where $\theta' = (97.7 - t')$, t' being the wet bulb temperature in degrees Fahr. and V the velocity in feet per minute.

The curves giving relation between H/θ and velocity (Fig. II.) and relation between temperature and wind velocity for dry cooling powers of 6, 8 and 10, (Fig. III.), were based on the old formula, and are therefore erroneous. The corresponding curves corrected to the new formula are given here with



NOTE. 1 METRE PER SEC. = 197 FEET PER MINUTE.



DISTRIBUTION OF GOLD IN BANKET ORE CLASSIFIED PRODUCTS WITH REFERENCE TO MILLING AND CYANIDING OPERATIONS.

By F. WARTENWEILER.

(Printed in *Journal*, June, 1921.)

DISCUSSION.

Dr. W. A. Caldecott: The Society is indebted to Mr. Wartenweiler for his paper embodying the results of long-continued and laborious oil flotation tests upon finely crushed banket ore products. It is somewhat remarkable that so many years should have intervened before further progress, since early in this century the important subject of gold distribution in banket ore products was investigated in some detail by means of other classification methods.

In considering the relative proportions of gold and pyrite separated by oil flotation, the fact that the author crushed all sand samples to pass a screen of 150 meshes per linear inch is of great importance, an effective oil segregation being thereby rendered possible of the gold and pyrite released from attachment to larger quartz particles. It does not, however, follow that the pyrite carried the gold, as galena does silver, in the original ore or sand grains, but merely that the fine crushing set free from the siliceous matrix many individual and separate gold and pyritic particles, and thus rendered the former available for amalgamation, or capable of separation together with the pyrite by oil flotation. This consideration is of great importance as it explains the failure of attempts in earlier years, accompanied by very large capital expenditure, to profitably employ, on banket ore tailing, concentrators of the vanner and Wilfley type.

From a report by Messrs. W. Bettel and J. H. Johns, published by the Witwatersrand Chamber of Mines on 2nd December, 1896, upon concentration by vanners in the Ferreira Mill, the following results are calculated:—

Products	Pyrite	Dwt. Gold per ton	Dwt. Gold per l. Pyrite
Tailing pulp before vanners ...	2.178	11.37	5.22
Tailing pulp after vanners ...	0.825	7.75	9.39

Hence the vanners recovered 62.1% of the pyrite, but only 31.8% of the gold.

The determination of the percentage of pyrite and assay value of each of the grades obtained by the author by sieving sand (Ref. 9) should illustrate the different ratios of gold to pyrite in the sized products both before and after cyanide treatment. The following table based on Mr. McA. Johnston's examination of a graded banket ore final tailing pulp ("Rand Metallurgical Practice," Vol. I., page 349), illustrates the disproportionate distribution of gold and pyrite in this product:—

Grade	% Pyrite (FeS ₂)	Dwt. Gold per ton	Dwt. Gold per l. Pyrite
+ 60 mesh ...	0.36	1.57	4.36
– 60 + 90 ...	0.62	1.36	2.19
– 90 + 125 ...	2.46	2.30	1.07
– 125 + 200 ...	1.20	1.80	0.67
– 200 mesh ...	2.94	3.44	0.86

A similar examination of the tailing pulp from a typical Far East Rand mine, such as the Geduld, would be of great interest.

As regards the distribution of gold and pyrite particles in the matrix of banket ore itself,* the former is usually embedded in a siliceous matrix, though frequently adjacent to pyrite, as shown in the I.M.M. paper and in Prof. R. B. Young's book on "Banket," which are referred to by the author, and as pointed out many years ago by Drs. Hatch and Corstorphine in a paper read before the Geological Society of South Africa, November, 1904, in the following terms:—

"Although rarely visible in the hand specimen, the gold can be easily studied under the microscope, if specimens known to be rich in it are examined. In the slides which we have examined, the noble metal occurs in irregular angular particles, often lying on the periphery of individual pyrites crystals, or in the interstices between aggregates of that mineral. We have seen no instance of the gold lying inside a homogeneous crystal or piece of pyrites. In many cases perfectly round pieces of pyrites may be observed to be bounded by gold particles."

From a metallurgical standpoint, the author's contention appears proven that very fine crushing is a necessary preliminary

* See "Rand Metallurgical Practice," Vol. I., Chapter XI., p. 382.

to a good concentration of the gold by oil flotation.

Referring to the aqua regia tests, it is not clear why more encased gold was found in the sand original than in the residue, since, with sufficiently long treatment, the aqua regia should dissolve all accessible gold and pyrite in both cases, and hence the ultimate encased gold should have been the same in each case, as penetration of a solid siliceous envelope by cyanide solution can hardly be seriously maintained.

Incidentally it may be pointed out that since pyrite is soluble in aqua regia, the solvent action of the latter on gold is not confined to gold particles wholly or partially exposed in sand, but extends after dissolution of the pyrite to any gold particles lying between the joint surface of pyrite and silica in "mixed grains." Hence more gold is "accessible" to aqua regia than to cyanide solution in such mixed grains.

The author's deduction that - 200 mesh gold should be returned to the tube mills by the classifiers for further grinding has apparently in view its subsequent solution in cyanide, but as the bulk of Rand gold recovery is by means of amalgamation and two-thirds of modern crushing is done in tube-mills, the practical objective would appear to be efficient and prompt amalgamation of all free gold possible in the tube-mill overflow pulp. Coarseness of gold particles facilitates amalgamation, and recovery in this manner reduces the value of the final tailing pulp, thereby facilitating cyanide treatment and conducing to low cyanide residues and high total gold recovery. The same reasoning applies to the fine gold found to be amalgamated by the author, and after fine crushing in the cyanide pulp and sand charge, which would presumably have been easily recovered in the reduction plant by amalgamation and not by cyaniding, had been economically practicable to carry the crushing of the ore to the same degree of fineness in the Village Deep crushing plant as in the tests recorded by the author.

SYMPOSIUM MINERS' PHTHISIS

Mr. William Allen: I venture to give you an idea for the prevention of dust being thrown into the atmosphere during drilling operations.

My idea is roughly to cover the collar of the hole being drilled with a sort of cap which of course will allow the jumper the movement necessary for the drilling. From

this cap the air would be exhausted through a tube by means of a compressed air jet. The air, passing through a dust trap, would be freed from dust and delivered to the atmosphere.

The cap could be made of stout leather on a steel frame and could be held in position over the collar of the hole by means of a jointed arm clamped to the bar of the machine. The cap could be provided with three openings:—First, the exhaust pipe; second, an opening to which a water hose could be attached so that the water would play on the collar of the hole; third, a drain pipe to carry away the sludge. The cap could not, of course, be made to fit the face or the jumper closely. That, however, would not be at all necessary since the exhausting of the air in it would cause a draught of air to pass inwards through these spaces which would pick up those dust particles which had escaped the water and carry them with it into the exhaust tube and thence to the dust trap.

The dust trap could be one of various kinds. Probably the simplest and most efficient type would be one using sticky surfaces placed in the form of baffles in a small box. The size of the box, number of baffles, size of baffles and best substance to be used to render the surfaces sticky could best be found by experiment. These baffles could be taken out and recoated with the sticky substance daily or at such intervals as would be found necessary by experience.

The exhausting apparatus could be of extremely simple construction. A fine jet discharging into the pipe leading out of the dust trap would use very little compressed air and at the same time give a very fair suction.

I do not see any very great objection to the use of this cap with any type of machine at present in use on the Rand. It could be set in position in a few seconds and moved from one hole to another in even less time. The necessity for long extra hoses could be done away with by having a T piece inserted in the hose feeding the machine with compressed air about three feet from the machine. From the end limb of this T piece a short piece of piping would feed compressed air to the exhausting jet. The only other extra hose necessary would be that connecting the dust trap to the cap. This would require to be about ten feet long. The dust trap and jet could then be on the footwall behind the machine.

The whole apparatus would be extremely

simple, and could easily be made such that it would stand the ever-present rough handling to which everything used underground seems doomed.

Notices and Abstracts of Articles and Papers.

CHEMISTRY

PREPARATION OF FULLER'S EARTH (FOR TREATMENT OF MINERAL OILS).—"The bleaching action of fuller's earth on mineral oils is independent of its chemical composition, and depends on its power of selective absorption. The following factors are important: The longer the column of earth the better the bleaching effect; the coarser the earth the more rapid the flow and the poorer the bleaching effect; the higher the temperature the faster the flow, and the poorer the bleaching effect. Filtration should, therefore, take place at the lowest temperature compatible with the fluidity of the oil. The first burning of the earth should take place at about 600° to 700° F. (315° to 370° C.); this merely removes water and organic matter. There should be no fusion. After use the earth may be revived by further burning at 1050° to 1100° F. (565° to 590° C.); with Florida earth the optimum temperature is 1100° to 1200° F. (590° to 650° C.). Very serious loss in efficiency results from over-burning."—W. C. PHALEN, *Chem. and Met. Eng.*, 1919, 21, 169.—*Journ. Soc. Chem. Ind.*, Feb. 16, 1920, p. 97A. (J. A. W.)

FURTHER PROBLEMS IN CONTACT CATALYSIS.—"Several features of the phenomenon of contact catalysis in cases where carrier action or formation of intermediate compounds does not take place, are discussed by the author. Most contact agents have a porous or finely divided structure, e.g., bog iron ore, firebrick, platinum deposited on asbestos, etc., and platinum gauze, which acquires activity in use, is found to have developed a corrugated, pitted surface. Although these porous materials are also adsorbent, yet the two phenomena of catalysis and adsorption are quite distinct. Thus, although charcoal shows marked adsorptive action towards carbon monoxide, oxygen, and carbon dioxide, its activity in promoting the oxidation process is practically nil compared with metallic oxides. On the other hand, ethylene and oxygen react at ordinary temperatures in presence of charcoal. The differentiations may be due to the relative adsorptive capacities of charcoal and metallic oxides in one case, and preferential adsorption of particular gases by charcoal in the other. Data in regard to the amounts of gases which may be adsorbed separately or from a mixture are still scanty. The effect of poisons on catalytic agents may be explained by their interference with the adsorptive properties of the catalyst, but the time factor or velocity of adsorption must be taken into consideration, and since the normal time of contact is extremely short, the effect of the poison may be due to a reduction of the velocity with which adsorption occurs. Charcoal used for gas masks gave very different results in the "clean" and "unclean" condition. The adsorption curves indicate that, although the ultimate amount adsorbed would be the same, yet the clean charcoal has a much higher velocity of adsorption in the early stages. The nature of the adsorbent is important, and an alteration of its chemical re-

activity influences its catalytic activity. Copper oxide wire is reduced by hydrogen at 300° C., but if the copper is oxidised at a lower temperature, subsequent reduction will occur at a temperature as low as 100° C., and such copper oxide will also catalyse hydrogen and oxygen at 100° C. The increase of catalysis by promoters, such as small quantities of chromium oxide added to iron oxide, has not been fully accounted for."—H. S. TAYLOR, *Trans. Amer. Electrochem. Soc.*, 1919, 167-173.—*Journ. Soc. Chem. Ind.*, Feb. 16, 1920, p. 91A. (J. A. W.)

FIXATION OF ETHYLENE PRESENT IN COKE-OVEN GAS AS ALCOHOL AND ITS DERIVATIVES.—"Peat coke has been used successfully at the Skinningrove Iron-works during the war for the separation of ethylene and other gases from the gaseous products of carbonisation processes (this *Journal*, 1919, 857A). Though this method is advantageous in some cases, sulphuric acid (95%) is preferable as an absorbent when liquid derivatives of ethylene are to be prepared. The hot gas from the retorts is cooled and purified in the usual manner, and then passed through a drying scrubber in which 80% sulphuric acid is circulated. The gas is then heated to 60° to 80° C., the hot retort gases being utilised for this purpose, and is then passed into the ethylene scrubbers, which contain 95% sulphuric acid, also maintained at 60° to 80° C. The acid flows in the opposite direction to the gas, the acidity being reduced by about 10% on leaving the scrubbers. The alcohol is distilled off by means of superheated steam, or acetic acid may be obtained by electrolysis or by the use of ozonised air. Any sulphur dioxide formed by the reduction of the sulphuric acid is recovered by interaction with hydrogen sulphide in the crude coke-oven gas. A plant dealing with 5,800 tons of coal per week should yield 9,280 gallons of absolute alcohol, taking a 50% conversion of ethylene to alcohol as actually obtained. The reduction in calorific value of the extracted gas is small."—E. BURY, *Cleveland Inst. Eng. Gas J.*, 1919, 148, 718-721.—*Journ. Soc. Chem. Ind.*, Feb. 16, 1920, p. 91A. (J. A. W.)

LIQUID AIR EXPLOSIVES.—"So far as mine rescue is concerned, the utility of liquid air has already been established in the Notts. and Derbyshire coalfields, as liquid-air plants have been installed at the Chesterfield, Mansfield and Ilkeston rescue stations. Its usefulness in blasting operations has now been ascertained, and on Tuesday, the 16th November, a demonstration of what it can do in this direction was given by the Liquid Air and Rescue Syndicate, Limited, at the Fleasley Junction quarries, Mansfield Woodhouse, Nottinghamshire, owned by Mr. William Sills. The demonstration was witnessed by a representative gathering of colliery owners, managers, and mining officials.

The Syndicate, the Headquarters of which are at Park Royal, London, was formed in 1913 with the object of manufacturing liquid-air plants. At that time liquid air was looked upon as a scientific curiosity, but the fact that the Syndicate has supplied plants to various mining centres in this country and the Colonies for mine rescue work is evidence of it having reached the practical stage. Experiments with a view to ascertaining its further utility were being carried out in 1914, but these were interfered with by the outbreak of war. After hostilities had ceased, however, the experiments were proceeded with, and it was found that liquid air could be utilised with marked effect as a con-

stituent of explosive.

"The explosive consists of a cartridge formed of a stiff paper wrapper filled with carbonaceous material, which varies according to the work to be done. Filled with cork dust, sawdust, peat, or similar material, the cartridge itself is non-inflammable and perfectly harmless. The other component is liquid air which contains about 90 per cent of oxygen. The cartridges are soaked in liquid air for a brief period, usually five minutes, and are then taken out, being ready for use immediately or during the space of fifteen minutes. They can be fired either with a detonator or an ordinary safety fuse. An important factor in connection with this explosive is that, in case of a miss-fire, the cartridge can, after a lapse of time, be taken out with safety, as the liquid air will have then evaporated.

"The blasting was carried out in magnesian limestone, the boreholes being 1½ in. diameter. The holes were placed as required for the ordinary working of the quarry, and the stone being required for fine burning the charges used were, except in the final shot, for producing a shattering effect. All the shots were fired electrically, one of the cartridges in each case having a No. 6 detonator affixed, placed as near the centre of the charge as possible. The cartridges were dropped into the holes without special precaution and pressed down with a wooden rammer, ordinary earth stemming being used. The particulars of the shots are as follows —

No.	Depth of hole	No. of cartridges and size (lb.)	Result
1	8	No. 2½ × 300	Rock well shattered, but not a great quantity actually pushed out
2	8	Seven 2½ × 300	This shot was immediately behind No. 1 and was quite a success, shattering and displacing its own section and also the lower stone of No. 1.
3	8	Seven 3½ × 300	Very good, the rock being well shattered and displaced
4	7	Three 3½ × 200	Do
5	6	Four 3½ × 200	Do
6	6	Two 3½ × 200	Do
7	7	Five 2½ × 300	Very good; rock well split into useful pieces

"The holes were in each case drilled at a distance from the face approximately equivalent to the depth. On holes being bored vertically, the stones were fired in approximately three minutes from the time of commencing to insert the cartridge."—*Iron and Coal Trades Review*, 19th November, 1920, p. 721. (A. W.)

GRAVIMETRIC DETERMINATION OF NITROGEN.—The following procedure is recommended for the determination of nitro- and azo-nitro-nitrates (March, J., *Anal. Chem.*, 1905, 100, 1) of the mineral solution containing 0.01–0.05 g. NO_2 is acidified

with 1 cc. of glacial acetic acid, then treated at 60°–70° C. with 10 cc. of a perfectly clear 10% solution of nitro acetate, and allowed to stand for 24 hours in the dark at 15°–20° C. The precipitate is collected on a small pad of cotton wool in a cup-shaped filter, and washed with 50 cc. of a saturated solution of nitro-nitrate at the ordinary temperature. The precipitate is sucked as dry as possible, and dried at 100° C. for 2–3 hours. Sulphates and iodates are without influence on the results, but chlorides produce small errors, corrections for which are shown in a table."—L. W. WINKLER, *Z. angew. Chem.*, 1921, 34, 46.—*J.S.C.I.*, 31st March, 1921, p. 198A. (A. W.)

MISCELLANEOUS.

DETECTING SMALL QUANTITIES OF PETROLEUM (MINERAL OIL).—The increasing demand for petroleum has stimulated the search for oil by many who do not know its natural appearance and characteristics. The field tests described here are designed to indicate whether samples of rock and similar material contain petroleum or other closely related hydrocarbons. Heat tests and solvent tests are described.

Small Sample Representing the Richest Material.—The sample of oil-bearing rock, sand or oil shale should be about the size of a hickory nut (2 oz.). Crush to a fine powder with mortar and pestle or on some smooth, hard surface. Dry carefully in a dish placed in the sun or on a heated stone or brick. High temperature must be avoided.

Sample Representing an Average of Large Masses of Material.—Quarter down a large sample, breaking finer as bulk decreases. Finally reduce to a 2 oz. sample, grind to powder and dry as above.

Place one-third of a teaspoonful of the dry powdered sample in a glass test tube sealed at one end. Hold the tube in a horizontal position; heat slowly in the moderately hot flame of a soldering torch, large alcohol lamp or gas jet, until the lower part of the glass tube becomes dull red. If the sample contains petroleum one of three things will happen, depending upon the quantity of oil in the sample; if the quantity is small, a cloud of white fumes will gather in the tube between the sample and the mouth of the tube; if the quantity is larger, the cloud will be very thick, and tiny drops of oil will condense upon the walls of the tube, and if the quantity is great, enough oil will condense to form small drops that will coalesce sufficiently to be named. The fumes will have the odour of petroleum.

This heat test will apply to rocks containing free petroleum and also to rocks such as oil shales, coals and similar substances in which there may be practically no petroleum, but from which it can be obtained by destructive distillation.

Certain heat tests applied to earthy material containing organic matter derived from decomposed vegetation will give a visible vapour cloud similar to the cloud produced by heating petroleum containing rock or sand. However, the odour given off are totally unlike, and can with practice be distinguished. Rock samples should be free from moss or lichen. Should the sample contain sulphur, the usual white cloud will appear in the heat test, but the characteristic odour of sulphur dioxide will be detected.

Solvent Test.—Either pure chloroform or pure tetrachloride of carbon may be used as a solvent. The purity may be tested by passing three teaspoonfuls through a folded filter paper, then evaporating gently to dryness. If the solvent is pure, no appreciable residue will remain. Place a teaspoonful of the dried powdered sample with three teaspoonfuls of chloroform in a 4 oz. bottle with glass stopper. Shake the mixture at intervals for at least an hour. Filter through filter paper and collect the filtrate in a second bottle. If the filtrate contains petroleum it will be coloured a shade of amber or yellow brown, the shade generally depending upon its quantity in the sample. Pour the filtrate into a shallow porcelain dish or china saucer, and evaporate in a well-ventilated place. If the original sample contained petroleum the dish will show a yellow or amber coloured stain, the intensity of which will depend upon the quantity of oil in the sample. This test is conclusive only applied to material containing petroleum, asphaltic paraffins, or vegetable waxes and resins. It is of no practical value if applied to oil shales, peats, lignites or other minerals from which oil is obtained by destructive distillation, except that they may contain some true bitumen. It is recommended, where possible, that both heat and solvent tests be carried out.

It is unsafe to evaporate chloroform or carbon tetrachloride in a poorly ventilated room on account of obnoxious and poisonous gases formed.

Oil Films on Springs and Pools.—A few substances leave films on water that may be mistaken for an indication of petroleum. Such films can be distinguished from oil films by their brittleness. If stirred they will break into patches, having sharp corners and irregular edges. An oil film if stirred will form patches, having smooth, rounded edges, and these only after considerable resistance to breakage. This physical test may be confirmed by the solvent test on a sample of film. Fill a clean glass bottle holding about half a gallon, two-thirds full of the skimmings of film; add three teaspoonfuls of chloroform, cork and shake. If the film is due to petroleum, the chloroform will become more or less amber coloured. Allow the chloroform to settle, pour off the water and wash with several lots of water. Transfer the chloroform to an evaporating dish and evaporate. Petroleum will be indicated by a more or less amber coloured stain and by odour.—E. T. FRICKSON, *Eng. and Mining Journ.*, N.Y., July 9, 1921. Geological Survey of U.S.A. (F. W.)

CENTRIFUGALLY CAST PIPE.—"Mr. A. F. Macallum, of Ottawa, in a paper recently read before the Montreal Branch of the Engineering Institute of Canada, dealt with the process developed by Senhor de Lavaud, a Brazilian engineer, for casting iron pipes by a method involving the application of the principle of centrifugal force to the molten metal. Remarking that present specifications for cast-iron pipe call for an iron having a tensile strength of 19,000 lb. per sq. in., the author said that when higher standards are attempted with the present foundry practice and mixtures, the pipe is apt to be brittle. Pipes cast by the De Lavaud process are now being introduced in Canada, after exhaustive comparative tests with the ordinary standard cast iron pipe.

"The author has studied the new process, in which a regulated quantity of molten iron is intro-

duced into a revolving water-cooled cylindrical mould, whereby the centrifugal force drives and spreads the molten metal uniformly upon the inner surface of the mould. Within a few seconds the pipe is withdrawn at a red heat from the mould. It is brittle, on account of the outer surface being chilled, but, after being annealed, it becomes tough and much stronger than ordinary cast-iron pipe, as proved by the recent tests made by Professor Gillespie, of Toronto University. The pipe made under these conditions has a decided contrast in structure to pipe cast in sand moulds, and has not the segregation of impurities often found in sand-cast pipe. The centrifugal pipe is a homogenous, dense, fine-grained iron throughout, having no water or gas bubbles, and because of this density and strength, can be made much thinner. It has high tensile, cross-bending and resistance to shock values. In the tests made by Professor Gillespie a 6-in. pipe (0.28-in. thick) made by the centrifugal method was compared with a 6-in. ordinary sand-moulded pipe 0.51-in. thick), and out of the same iron, with the following results:—

	Centrifugal Pipe.	Sand-cast Pipe.
Tensile strength		
(lbs. per sq. in.)	39,000	16,000
Mod. of elasticity	14,500,000	8,860,000

"It is apparent, therefore, that the new type of pipe can be made much thinner than the sand-moulded pipe. For example, a 12-ft. length of 6-in. pipe weighs 280 lb., as compared with 430 lb. for a sand-cast pipe of the same diameter.

"In soils found in Ontario cast-iron pipe suffers very little corrosion. The author has removed a section of old English cast-iron pipe laid in 1859 in Hamilton that showed no corrosion whatever, after being in the ground over 50 years, having even the weight marks clearly legible. This old English pipe was made much thinner than called for in the present-day specifications, and, being on a rising main, is still in service under more severe conditions from pressure than when laid. The tests on De Lavaud centrifugal cast-iron pipe show it, to all intents and purposes, impervious to corrosion, probably due to the fact that the metal, being cast under pressure, is of such close grain as to resist the attack of corrosive matter.

"The centrifugal cast pipes have a smooth exterior and interior surface, and, besides reducing hydraulic frictional losses, take a uniform surface coating. While the pipes are cast with standard bell ends, they machine easily, and, because of the method of manufacture, the wall thickness is exactly uniform throughout, and suitable for a threaded or straight wall joint if desired."—*Iron and Coal Trades Review*, 17th December, 1920 (J. A. W.)

Changes of Address.

HASTINGS, B. J., *1/o Springs Mines, Ltd.*: Brakpan Mines, Ltd., P.O. Box 3, Brakpan.

HERALD, A. J., *1/o Knights Deep, Ltd.*: Simmer & Jack Prop. Mines, Ltd., P.O. Box 192, Germiston.

WADDINGTON, S. C., *1/o Mt. Ngwibi, Natal*: P.O. Box 1146, Johannesburg.

WRAITH, C. O., *1/o Kaapsche Hoop*: S.A. Coal Estates, P.O., Blackhill.

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Proceedings

AT

**Ordinary General Meeting,
17th September, 1921**

The Ordinary General Meeting of the Society was held in the Assembly Hall, Scientific and Technical Club, 100, Fox Street, Johannesburg, on Saturday, the 17th September, 1921, at 8 p.m., Mr. C. J. Gray (Vice-President) in the chair. There were also present:—

26 Members: Prof. G. A. Watermeyer, Messrs. F. W. Watson, J. R. Thurlow, J. Chilton, J. Hayward Johnson, A. King, J. E. Thomas, John Watson, H. A. White, J. A. Woodburn (Members of Council), J. Q. Bradwood, Dr. W. A. Caldecott, R. A. Cooper, A. F. Cresse, Jas. Gray, F. Heimersloot, C. A. Meiklejohn, T. Procter, J. F. Pyles, B. Schlesinger, T. J. R. Smythe, J. Thurlund, W. E. Turner, J. T. Triggs, E. M. Weston, and H. P. S. Wilkes.

4 Associates: Messrs. W. Andersen, O. A. Gerdorf, R. W. Irwin, and V. Powers.

2 Visitors: and H. A. G. Jeffreys (Secretary).

MINUTES

The Minutes of the Annual General Meeting, held on the 25th June, 1921, as recorded in the June *Journal*, were confirmed.

NEW MEMBERS

A ballot was taken for the election of new members, and the following were declared unanimously elected:—

BARRIS, JAMES F. H., Northern Lime Co., Ltd., P.O. Box 100, Johannesburg: General Manager.

BARTON, ROBERT A., Idleness Road, Hill Despatched Co., Ltd., Braham Hill, N. Rhodesia: Mining Engineer.

DODDS, WILLIAM B., City Deep, Ltd., Johannesburg: Reduction Officer.

GEORGE, JAMES, P.O. Box 7060, Johannesburg: Reduction Worker.

HASELDEN, F., P.O. Box 858, Johannesburg: Solicitor.

IRELAND, HERBERT J., P.O. Box 6197, Johannesburg: Engineer.

LANGLER, GERARD H., P.O. Box 3762, Johannesburg: Engineer.

OSBORN, SIDNEY S., Glynn's Lydenburg, Ltd., Sabie, Transvaal: Reduction Officer.

SMITS, BASIL A. S., P.O. Box 858, Johannesburg: Solicitor.

WILLIAMS, ARTHUR T., P.O. Box 24, Delmas, Transvaal: Engineer.

The Secretary notified that the following gentlemen had been admitted as Associates by the Council:—

ALEXANDER, SAMUEL, Bettelheim Buildings, Johannesburg: Director of Companies.

BARRY, E. A., Modder "B" G.M. Co., Ltd.: Chief Smelter.

DEAKIN, C. E., Village Deep, Ltd.: Underground Manager's Assistant.

GORDON, G. B., 3, Corporation Buildings, Johannesburg: Consulting Engineer.

GREEN, F. V., P.O. Box 7017, Johannesburg: Manager, S.A. Locomotive Works.

HICKS-FORD, J., British South African Explosives Co., Ltd.: Secretary.

LYDE, G. A., Portland House, Commissioner Street, Johannesburg: Fire Assessor and Insurance Manager.

MADEB, J. H., P.O. Box 6096, Johannesburg: Managing Director, C. Wharton Hood & Co (S.A.), Ltd.

POWERS, VICTOR, P.O. Box 1092, Johannesburg: Mechanical Draughtsman.

SIMON, R. A. H., National Bank of South Africa, Ltd., Head Office, Pretoria: Inspector.

STEVENS, P. J., 42, Standard Bank Chamber, Johannesburg: American Trade Commissioner.

As Student:—

SANFORD, VICTOR N., 263, North Broad Street, Newark, N.J., U.S.A.

THE ACIDITY OF MINE WATERS.

By F. W. WATSON, B.Sc., F.I.C., and
R. A. COOPER.

The neutralisation of circulating underground waters has been discussed frequently, but as the fundamental chemical principles involved in the operation are still either unknown to or ignored by responsible persons, and serious damage thereby caused, it may be not untimely to bring the matter forward again.

In the September, 1913, *Journal* of this Society there appeared an excellent paper on this subject by Dr. J. Moir, who confined himself largely to the study of different indicators. He advised the use of methyl orange as indicating waters sufficiently neutralised to avoid corrosion. With the advent of high speed and high pressure pumps this point has been found to be highly unsatisfactory, and waters neutralised beyond it have still corroded Sulzer pumps with amazing rapidity.

A later paper was read before the S.A. Institution of Engineers by Messrs. Wartenweiler and Croghan in October, 1919. Their paper dealt principally with the mechanical aspects of the subject, such as rates of precipitate settlement and volumes of precipitate formed, and they also considered the comparative costs and efficiencies of sodium carbonate, calcium carbonate and burnt lime.

As the present paper is dealing entirely with the chemical side of the question, we will consider only the action of lime, this being the reagent most largely used. In passing, however, it may be noted that with the use of calcium carbonate there is no possibility of alternating caustic alkalinity and acidity, the effects of which are commented on later in this paper, but the neutralising action of the carbonate is slow, and only the most finely divided material is available.

Corrosion of exposed metal work in the mine will always be present to some extent, but it is greatly accelerated when acid water is in flowing contact with the metal. Active corrosive agents in mine water on the Rand may include sulphuric acid and a considerable variety of sulphates of metals, the most persistent of the latter being iron, aluminium, manganese and nickel sulphates.

Other acids or their salts are not normally present except sodium chloride in small quantity. It is the behaviour of these various sulphates during the course of neutralisation that is most often misunderstood. The term "free acid" appears to be a stumbling block to many, and is probably responsible for many errors in calculation. It is usually meant to indicate acid which is in excess of the amount required to form normal sulphates with the bases present, and an attempt to determine its amount is made by titration with a standard alkali solution using methyl-orange as indicator.

A number of complete analyses of typical corrosive mine waters have been made, and they invariably show that instead of there being any excess of sulphuric acid present there is a marked deficiency of the sulphate ion below the calculated amount required to form normal sulphates with the bases present.

The following is a typical analysis (expressed as parts per 100,000):—

	Bases as Oxides Parts	SO ₃ required to form normal Salts Parts
Ferrous oxide ...	3.2	3.6
Ferrie oxide ...	11.4	17.1
Aluminium oxide ...	40.0	94.1
Nickel oxide ...	6.7	7.2
Cobalt oxide ...	Traces	—
Manganese oxide...	2.2	2.5
Calcium oxide ...	56.0	80.0
Magnesium oxide ...	36.6	73.2
Sodium oxide ...	41.1	45.4
Potassium oxide ...	1.0	0.8
Silicon oxide ...	10.8	—
Chlorine	5.2	—

(Sodium Chloride 11.1)

Sulphuric Anhydride (SO₃) 277.8 parts actually found. 323.9 parts called for.

The shortage of the SO₃ actually present below that required to form normal sulphates is 46.1 parts per 100,000.

This water could obviously contain no "free acid" in the meaning of the term as indicated above, but, on the contrary, some of the metal sulphates were present in a "basic" condition, nevertheless the water was strongly acid to methyl orange indicator.

It is therefore apparent that the designation of the acidity indicated by methyl orange as "free acid" is frequently, if not always, a misnomer.

The use of neutral copper solution has repeatedly failed to indicate the presence of any excess sulphuric acid in the most corrosive waters.

The corrosive action of such waters is due to the presence of the $[H^+]$ ion liberated by hydrolysis of the metal sulphates in solution: it is this hydron which is the free acid of the water.

During neutralisation, metals are removed from solution in the form of precipitates, but remaining metal sulphates continually ionise and are corrosive until the neutral point is passed and all, or practically all, of the deleterious compounds have been decomposed. In the absence of any excess of sulphuric acid it therefore becomes the function of the neutralising agent to remove certain metals from solution.

A corrosive mine water containing ferric, aluminium, ferrous, nickel, manganese, magnesium and calcium sulphates was tested, and also the reactions of each individual sulphate determined.

1. Ferric sulphate alone of the above, turns methyl orange to the red colour indicating acidity, and it is also acid to all the common indicators. On the gradual addition of lime to the water the ferric iron was precipitated from solution when the original hydrogen ion concentration had been reduced from the original $[H^+] 1 \times 10^{-2}$ to $[H^+] 1 \times 10^{-3}$ or approximately from an acidity equivalent to $\frac{1}{10}$ to $\frac{1}{100}$ hydrochloric acid.

The water was then neutral to methyl orange, but acid to methyl red, phenolphthalein, rosolic acid, etc. The ferric sulphate percentage can be quite closely determined in weak solutions of the normal sulphate by titration with sodium hydroxide, taking the first change of tint of methyl orange from pink to salmon as the end point, but this change is difficult to detect when much of the reddish brown ferric hydroxide is precipitated.

2. Aluminium sulphate, the next compound to be decomposed during neutralisation, is neutral to methyl orange, and gives the salmon tint with this indicator which slowly fades during progressive alkali addition and shows no sharp change to yellow. It is acid to methyl red and indicators of the phenolphthalein class, and can be approximately determined by titration with sodium hydroxide in slightly warmed solutions

using methyl red indicator. The aluminium was removed from solution in the tested water when the hydrogen ion concentration was reduced to $[H^+] 1 \times 10^{-6}$ —equivalent to an acidity of about $\frac{1}{1,000,000}$ hydrochloric acid. The water was then slightly alkaline to methyl orange and neutral to methyl red, but acid to rosolic acid, bromo-thymol blue, etc.

3. During the next stage of neutralisation, ferrous sulphate and nickel sulphate are removed practically simultaneously. At this stage the point of true neutrality is just passed—the hydrogen ion concentration being approximately $[H^+] 1 \times 10^{-9}$ equivalent to $\frac{1}{100,000}$ alkali, and the water gives a taint alkaline reaction with phenolphthalein, rosolic acid, and bromo-thymol blue. It appears to be necessary to carry neutralisation to this stage whenever the water is to be handled by high pressure pumps or used in the reduction works: in the first case, because any ferrous sulphate left in solution rapidly commences to oxidise and produce the highly corrosive ferric sulphate, and, in the second case, because ferrous sulphate, or even precipitated ferrous hydrate, is an active cyanicide and deoxidiser.

4. Slight further addition of lime precipitates manganese hydroxide and silicic acid and small quantities of magnesia, beyond this point magnesia alone is precipitated. When the test water was maintained at an alkalinity to phenolphthalein equivalent to 0.008% CaO for 12 hours, the original magnesia content of 30 parts MgO per 100,000 was reduced to less than three parts.

The composition of the precipitates actually produced at each stage of the above neutralisation was as follows:—

Stages	1	2	3	4	5
Ferric oxide	95	2	—	—	—
Ferrous oxide	—	—	30	—	—
Aluminium oxide	5	96	—	—	—
Nickel oxide	—	1	68	—	—
Manganese oxide	—	Traces	1	5	—
Magnesium oxide	—	—	—	90	99
Silica	—	—	—	5	—

It is difficult to determine a satisfactory titration method for practical use which will safely indicate the decomposition of deleterious sulphates and at the same time not call for an excessive amount of alkali, as some indicators are destroyed by such precipitated bases as ferron and manganese hydroxides, e.g., methyl orange, the density of the precipitates in many cases obscured any change of colour, and there remains the

difficulty that the magnesium sulphate is constantly decomposed by a slight excess of alkali, thus always tending to change the alkaline colours of the indicators back to an uncertain neutral tint. This last factor is often very pronounced and troublesome. Obviously the correct procedure would be to abandon dye indicators altogether and use an ionometer, but, as yet, these instruments are expensive and delicate.

Considerable experience has shown that very rapid titration with $\frac{N}{1000}$ sodium hydrate using rosolic acid indicator gives excellent results in practice, the first appearance of a transient pink colour being taken as the end point.

In the case of an extremely highly mineralised water a rough determination may be first made, and then, to a second portion of the sample, about three-quarters of the required alkali is added, the solution rapidly filtered, and an aliquot portion of the filtrate taken for final titration.

The practice of adding an excess of alkali to a sample and then filtering off the precipitate and determining the residual alkalinity of the filtrate gives very erroneous results, depending on the excess of alkali added, the temperature of the solutions, and the speed of operation, because this time-temperature-concentration factor controls the extent of decomposition of the calcium and magnesium compounds. When a mine water contains so much ferrous sulphate that the indicator is obscured or destroyed by the dark green precipitate it is often useful to add a known amount of very dilute hydrogen peroxide before titrating; a blank titration using the same quantity of peroxide in distilled water, being made to ascertain any necessary correction.

Experiments are being carried out to determine whether the use of neutral citrates, etc., to prevent the formation of any precipitate during titration is practicable. In view of the very great expense actually incurred by neglect of correct neutralisation on several mine properties recently, it is an immediate and pressing necessity that rapid and accurate methods of testing be known and used, and that clear records be kept and periodically examined by those responsible for the upkeep of metal work underground. Continuous addition of lime to a circulating mine water in the absence of any large additions of fresh water from fissures, etc., will eventually result in super-saturating the water with calcium sulphate (sulphate of lime), which crystal-

lises out very rapidly when opportunity offers and obstructs pipe-lines and pumps.

This can be avoided economically in practice only by testing the water regularly and diluting with fresh unsaturated water when necessary, though in very urgent cases the addition of sodium carbonate to precipitate calcium carbonate from solution may be made to obtain immediate relief.

It should be noted that calcium sulphate is distinctly more soluble in slightly acid than in alkaline waters, but as corrosion proceeds very rapidly in solutions alternating between acidity and alkalinity it is necessary to maintain constant conditions one way or the other—alkalinity obviously being preferable. Such constant conditions can only be maintained by having an automatically controlled lime feeder which will hold at least 24 hours' supply of lime. The complete settlement of all precipitates formed during neutralisation is from the point of view of both the metallurgist and the engineer most safely carried out underground, because in most cases the precipitates are not only cyanicides and deoxidisers, but also they carry in suspension considerable quantities of siliceous grit, which is almost as destructive to high-speed centrifugal pumps as is acidity. Efficient settlement usually requires large reservoirs or large and easily cleaned filter beds, the former method being preferable, especially if some such reservoir as a disused stope, which can be easily closed at the bottom and fitted with sludge valves, is available.

In conclusion, we desire to thank the Rand Mines Metallurgical Department and Mr. K. L. Graham, Chief Metallurgist, for permission to publish this paper.

Mr. Andrew F. Crosse proposed a very hearty vote of thanks to the authors for their extremely interesting paper, which he would have great pleasure in studying carefully in the *Journal*.

The vote of thanks was seconded by Mr. Jas. Gray.

SYMPOSIUM: MINERS' PHTHISIS.

Mr. J. A. Woodburn prefaced his contribution by saying that though it had reference to the Addendum to the paper on the "Kata thermometer and its Practical Uses in Mining,"* published in last month's *Journal*, the Kata-thermometer and discussion thereon were so connected with the

* Original paper printed in *Journal*, November, 1920.

subjects which had been discussed in the Symposium on Miners' Phthisis, that he considered his contribution could be included under that heading.

When the original paper by Mr. Ireland was read it was stated that the Kata was quite as reliable as the average windmill anemometer used in mines, and was not liable to change of constant due to friction, etc., and was also more sensitive to low velocities, and the impression was made that it would be a more convenient and reliable instrument than the anemometer for estimating velocities in Rand Mines.

Then in the reply of the author to the discussion he says: "I am very sceptical of the accuracy of readings of air currents taken with the anemometer in underground drives and workings, especially where the air is usually eddying considerably, or even back-washing in places," but he does not claim any greater accuracy for the velocity as calculated from the Kata reading.

Now, in the Addendum just published, it is stated: "The new formulae explain some anomalies between velocities computed from Kata readings and those obtained by anemometer," and the inference seems to be that the anemometer readings were more correct and, strange to say, evidently at low velocities.

If one refers to the new diagrams as compared with the original it will be seen that to give a cooling effect of 10° reading, which is the figure recommended for hard manual effort with a working temperature of say, 75° a velocity of somewhat over 400 ft. per minute is required according to the latest diagram, whereas the original showed that this cooling effect would be produced by about 200 ft. per minute, and if you take a temperature of 80° the revised diagram shows a necessary velocity of about 750 ft. as compared with about 510 ft. per minute in the original diagram.

It would appear that the question of cooling effect must be kept strictly separate from ventilation, which should be the actual removal of the atmosphere, and Mr. Ireland suggests to indicate this when he suggests 10,000 cu. ft. of fresh air being added to 20,000 cu. ft. of circulating air. To get a cooling effect comparable to a velocity of 500 ft. to 800 ft. per minute, a fan would require to be practically placing direct on the person working, and this is where Mr. Gray stands, and I agree entirely with him, that Kata readings where the air is merely being stirred up locally, while they will give some

idea of the cooling effect in the working, are practically of little use as an indication of ventilation.

Although Mr. Ireland suggests various quantities of air to be in actual circulation throughout the mine, and although he seems to think the anemometer is not quite reliable, he does not state how he would measure the quantities, and this appears to me to be a most important point. In collieries, for many years past, the anemometer served a useful purpose in arriving at the actual quantity of air passing in the various sections of a mine, and important deductions have been drawn from measurements so taken, and from all the information so far gained regarding the Kata-thermometer it does not appear to be any more reliable. I therefore cannot help reiterating my remarks that until some more convenient and reliable instrument is forthcoming, the anemometer should be employed in the Rand mines much more than it is today, and comparative figures obtained of quantities circulating in the various sections of the mines and these figures kept month by month so as to show the changes which I feel sure would take place periodically.

Mr. Ireland, in speaking on the Miners' Phthisis Symposium, in the *May Journal*, says: "The physiologists in recent years have told us very definitely what is wanted, and one feels it is now up to the engineers to deliver the goods," and in my opinion the more extensive use of the anemometer in the mines will greatly assist the engineers towards that end.

Mr. John Watson gave autobiographical details showing his early and close association in the county of Durham with the family of the late J. J. Atkinson, the authority on scientific mine ventilation. He stated that he lived in Durham County for over 30 years, and is also fairly well acquainted with the Cleveland ironstone district of North Yorkshire, but does not remember a single case of miners' phthisis in Durham, Northumberland or the Cleveland district. Even in Cleveland the mines are ventilated by centrifugal fans of adequate dimensions and velocity running over the upcast shaft. For 35 years the mines of the Rand have been dependant, chiefly, for their supplies of fresh air upon the antiquated system of natural ventilation, which means that for a good many hours out of the twenty-four there is no ventilation to speak of.

Since 1886 these fields have produced up to the end of 1918 approximately

£589,000,000 sterling value in gold, but at great sacrifice of human life. Fifty-nine years ago the late J. J. Atkinson said: "The best mode of dealing with them (*i.e.*, fire-damp, choke-damp and other gases) appears to be to dilute them with very large quantities of fresh air, and to sweep them out of the mine by an energetic ventilation as fast as they are given off or generated." The speaker was strongly of opinion that if the mines of the Rand were better ventilated the use of candles might, in places, have to be given up, but that we should be troubled much less with miners' phthisis, for which the industry has now to pay large sums annually.

OCCURRENCES OF FIRE DAMP ON THE FAR EAST RAND.

By T. N. DEWAR.

(Printed in *Journal*, February, 1921.)

DISCUSSION.

Mr. C. J. Gray: In order to throw further light, if possible, on the origin of the fire-damp met with on the Far East Rand, I have thought it worth while to ascertain from official records under what circumstances fire-damp has been met with elsewhere on the Rand.

According to those records, several natives were burnt, two of them fatally, by an ignition of gas on 21 level development drive, Milner Shaft, on the Simmer Deep Gold Mine on the 29th May, 1911; a shift boss and a miner were injured by an ignition when examining the same place on the 31st May, 1911, and a native was fatally burnt by an ignition in raise 3450 E.R.I. in the Cinderella Gold Mine on the 17th March, 1913. There is little doubt but that the gas concerned in those accidents was fire-damp.

In the Simmer Deep fatal accident natives had been shovelling at the drive face for some time when one of the natives who was examining the holes with a lighted candle ignited gas which probably was issuing on a fault. When the shift boss was injured he placed his light up in a cavity about two feet broad with crystalline walls. The place was 3,900 ft. below the surface.

In the Cinderella accident a surveyor's boy, who was sent up a raise which had been standing for about a week before the

accident, was burnt. The raise had passed through a small dyke and the face was in broken quartzite. Inflammable gas was found after the accident to be escaping with water from two of the machine holes which were standing in the face.

On the 19th May, 1908, in the Simmer Deep Gold Mine, a sample of gas which bubbled up through a diamond drill hole 51 feet into the footwall at 12th level east of No. 8 incline was taken for analysis. The drill had just passed through a thin seam of shaly matter. The analysis by Mr. A. McA. Johnston gave:—

	Per cent by volume.		
Carbon dioxide	0.4
Heavy hydrocarbon	Nil
Oxygen	Nil
Carbon monoxide	Nil
Methane	77.3
Hydrogen	8.4
Nitrogen	13.9
			100.0

It is also on record that in 1903 inflammable gas was encountered in the Angelo Deep Gold Mine in shales in a borehole put down from the bottom of a vertical shaft, and that the hole was blocked by lead balls forced down by the drills, but I have not yet been able to obtain authentic details of that occurrence.

The information available, and more particularly that *re* the Simmer Deep, seems to support the idea that the fire-damp originates in shales in the Witwatersrand series rather than in coal seams in overlying strata, but is not quite conclusive.

Mr. John Watson said he would like to draw the author's attention to a paper "On the Tees Salt Industry," read by Mr. T. W. Stuart to the Newcastle-on-Tyne section of the Society of Chemical Industry, Vol. VII, 1888.

On p. 662 Mr. Stuart said: "With the view of ascertaining the presence of coal, of which 5,000,000 tons are annually consumed in and near Middlesbro', Messrs. Bell Bros. continued the boring in one instance to 250 ft. below the salt, when they found gypsum, magnesian limestone, then limestone and again gypsum and rock-salt interstratified with marl, and were obliged to stop in a bed of rock salt. The presence of this magnesian limestone lent colour to the belief that the coal might be below, but when they found small beds of salt it was

clear that they had still the prospect of great thickness of red sandstone to pierce, and the diameter of the bore having been reduced to one inch, they were compelled to desist at 1,355 ft. from the surface. At 1,313 ft., and while in the limestone, they found considerable quantities of gas evolved, of which the following is the analysis:—

Methane or marsh gas, CH_4 ...	76.9
Ethane, C_2H_6 ...	6.3
Nitrogen, N ...	16.8

100.0

Again, on p. 663 in the same paper, the same author says: "The rock salt contains a considerable quantity of gas at high tension distributed in cavities throughout its mass, which not only accounts for the effervescence of the brine when pumped, but also, while drilling, causes a frequent outburst of water, which it forces several feet into the air for many hours together. This gas has been examined by Prof. Bedson, who found it to consist of:—

Marsh gas ...	2.05
Nitrogen ...	97.95

100.00

In the proceedings of the Geological Society of South Africa, Dr. P. A. Wagner, in his Anniversary Address as President, entitled "Some Problems in South African Geology," January, 1917, referring to "The Saltpan on the farm Zoutpan," says: "On withdrawing a stick or any other object that has been forced down into the mud there is a fairly powerful evolution of inflammable gas. This, according to Dr. Moor, contains 64% methane, and 1.5% of hydrogen. Carbon dioxide is absent. The gas probably owes its origin to the decay of vegetable matter washed into the pan from the upper slopes of the 'crater'."

The solubility of methane, or marsh gas, in water has been discussed by the author and others; the 10th edition (1913) of Bunsen's "Chemistry, Inorganic and Organic," on p. 550 says: "100 cc. water at 0° C. dissolve 5.5 cc. of methane."

Mr. E. M. Weston remarked that, according to the technical press, in pumping out some old silver mines in America a special danger has arisen owing to the very large quantity of methane met with. If anybody were foolish enough to wish to pump out an old mine with a view to making a profit out of it, he should remember that

DISTRIBUTION OF GOLD IN BANKET ORE CLASSIFIED PRODUCTS WITH REFERENCE TO MILLING AND CYANIDING OPERATIONS.

By F. WARTENWEILER.

(Printed in Journal, June, 1921.)

DISCUSSION.

Mr. H. A. White: In my previous printed remarks on this paper the restoration of the technical statistical term "correlation" in place of the printer's substituted "co-relation" is required in order to make the meaning clear.

The base of all such examinations as the present is an idea that there is some close physical connection between the gold and pyrite present. In order to establish the truth of this hypothesis it is obvious that the methods adopted for examination of various products must not be such as will force the very association which is to be established. Methods of panning, flotation, or the use of heavy solutions will inevitably cause an apparent association between any heavy or floatable minerals present, and cannot therefore aid in the solution of the problem. Gold attached to a pyritic particle is much more likely to be found in such "concentrates" than if it is attached to a piece of quartz of equal size, as the combination is heavier and more readily floated.

If a solution of the theoretical problem is sought the only apparently available method would be to roast the product to the stage where the pyrite becomes magnetic through loss of a portion of the sulphur. A magnetic separation would then favour the apparent association of quartz with gold in opposition to result of more usual methods. If the association of pyrite with gold were manifested after this ordeal, little doubt could be raised that the physical connection was real and not merely a result of experimental methods.

A careful examination of the results given in this paper suggests that the connection between pyrite and gold is in reality adventitious, and thus supports the well known results quoted in Dr. Caldecott's contribution to this discussion.

References (1) and (2) render clear the fact that the more closely the concentrate is restricted to FeS_2 the more gold goes to the gangue. Thus 3.11% concentrate at 55.1

dwt. becomes expanded to 5.81% at 36.20 dwt., and allowing for original sample value differences, the value of the added 2.70% was at least 8.6 dwt.

References (11) and (12) show that for equal sizes of particle the extraction by cyanide is greater for the pyritic portion than for the gangue.

Thus gangue	-90+200	...	87.2%
pyrite	do.	...	86.5%
gangue	-200	...	81.6%
pyrite	do.	...	94.1%

This suggests that the association between quartz and gold is more intimate than between gold and pyrite.

The deduction to be drawn from above observation is that though preferential grinding of heavy particles is desirable, yet the lighter portion of the ore can by no means be neglected.

It may be pointed out in passing that extractions of gold by means of aqua regia require prolonged washings to overcome the adsorption tendencies in order to secure concordant results.

Though the author points out that his paper does not aim at indicating possible extraction by flotation methods, yet the figures given support the general belief that higher extractions, or even as good, cannot be secured on Rand banket by this method.

Mr. A. King: Mr. Wartenweiler's paper has added to our knowledge of the necessity for fine grinding of Rand ore. Apart from the better recovery by amalgamation when fine grinding is possible, it is well known that the total recovery by amalgamation and cyaniding is higher than when a coarser final pulp is obtained. The results given in references 9 to 12 of the paper make this fact clear, apparently there being about 10% higher extraction by cyaniding from the -200 mesh product than from the +90 product; this appreciable difference is also found between the extractions from the -200 and the +90 mesh pyritic portions.

Even with reasonably good classification free gold enters the cyanide works, but is readily dissolved during treatment, so that in saying free gold should be returned to the tube-mills the author is asking for ideal conditions which can scarcely be obtained in practice, and, if obtainable, would mean re-grinding, or at least re-elevating, a large proportion of the pulp already sufficiently fine for cyanide treatment.

The author has made no mention of the limit to which fine grinding may be economically carried. This must be largely

dependant upon the value of the ore milled, and no doubt the author, from the large amount of data which he has collected, has some definite views on this point which would be of interest to members. There is also a practical limit to the desirable fineness of sand, after clean separation of slime, beyond which the product is no longer freely leachable, and beyond which there appears to be little or no improvement in extraction: this limit is apparently about 68% or 70% of -90 mesh product in sand.

A RESUME OF STANDARD METHODS IN SAMPLING, ANALYSIS AND CLASSIFICATION OF COAL.

By A. TREVOR WILLIAMS, M.Sc., B.A.

(Printed in *Journal*, July, 1921.)

DISCUSSION.

Mr. J. Q. Braidwood: The first paragraph in the paper is one I take exception to. This paragraph is essentially one of the most important in the paper, as it shows that the value of the paper depends, apparently, on the reliability of the authorities quoted, and not on personal experience and research by the author.

With regard to the reliability or practicability of the methods mentioned by the author of the paper, or their applicability to this country, I am afraid I must disagree to a very considerable extent. I question whether they may be considered as an improvement on methods in use here in 1908—gradually improved since, and standardised by the South African Engineering Standards Committee* (now the British Engineering Standards Committee, S.A. Branch). A similar but in my opinion unnecessarily elaborated system for commercial purposes with drawings and unnecessary multiplication of operations was published by the Bureau of Mines, Washington, in 1916, about four years subsequent to the South African publication, which gives one the impression that it is the work of a scientific gentleman who has lost sight of the fact that, however accurate a system of sampling may be, there are always small errors due to various well-known causes which make elaborate sampling methods and apparatus,

* Report, January, 1912.

unnecessarily expensive. No good purpose is served by such elaboration, as nothing kills a good idea quicker than unnecessary or high cost.

I must presume, for want of other and more certain knowledge, that the paper in question has been written with a view to assisting us in this benighted part of the world (or so it is generally assumed to be elsewhere); to give us an idea of what is being done in England so that we might gratefully follow the lead of the reliable authorities quoted, who have had one or two years' experience in selling coal on the calorific basis, as against a dozen years here. We are always pleased to know what others are doing elsewhere, but by past bitter experience we have found that to apply home methods here without very thorough investigation and experiment is courting disaster. I find that in the third paragraph of the second column, only English and American research Associations and authorities are mentioned. It is possible that no such remark as attributed to Mr. Sinnatt can be found in the pamphlet entitled, "Standardisation of coal sampling," published here in 1912, which may be due to the fact that we assume that those entrusted with such work realise their responsibility and the necessity for carrying out intelligently the simple and effective methods in use here, or that they will immediately be replaced by someone who can.

I would like to discuss another quotation near the foot of the second column, "The principle underlying sampling and its possible errors."

"To be truly representative of the whole weight of any consignment of coal a sample should not only contain a portion from every different part of coal, but also the correct proportions of large and small coal, and of large and small pieces of foreign matter and impurities."

The foregoing has many objectionable features likely to cause trouble, particularly if in the hands of a non-technical person, perhaps a layer of coal. It does not say that this should be weight in sample, in proportion to quantity of such material present in the bulk, although some such idea is conveyed later with regard to large and small coal. This gives one the idea that all small coal is inferior in calorific value to larger coal, which is not always the case, depending as it does a great deal on the frequency of the coal and method of mining.

With regard to the engineer mentioned on

page 2, I can only suggest that what we call a fitter in this country is meant.

I am in agreement with the statement about "errors" being traced "to an underestimated notion of what the weight of a sample ought to be," yet lower down I note weight of original sample should be 39,000 lb., and I would like to point out that it is easy to make rules which it would be absurd or impossible to carry out. For example:—If I went out to a mine and suggested that a 39,000 lb. sample should be taken, it is quite probable that the resident engineer would say, "Why not take the whole blooming truck." Engineers in this country often sacrifice the more cultured methods of speech to convey an incontrovertible fact in a few words.

From experience, I would say that to assume the smallest weight of a sample to be 1,000 lb. or half a ton for 100 tons bulk is misleading. Such a large quantity has been proved to be quite unnecessary. Further, to give a sampler of the ordinary human man type instructions such as, "In obtaining the gross sample great care must be exercised to ensure the presence in it of the proper proportions of large and small coal, and large and small impurities" would result in hopeless muddle. I say that it is not humanly possible for anyone to accurately estimate the quantity of large or small coal or impurities in a bulk consignment; in fact, such an instruction would wreck coal sampling if carried out, also if a coal sample of 39,000 lb., or even 1,000 lb. had to be sieved over a $\frac{1}{4}$ in. sieve, the gain would be infinitesimal.

In the sixth paragraph of the second column on page 2 we are told to "Run a shovel along the bottom of the wagon after enough coal has been unloaded to allow the coal to assume its natural shape" (I presume "natural shape" means angle of rest on the resulting slope due to removal of a part of the coal).

I am very definitely opposed to running a shovel along the bottom of the wagon unless I want to get a sample of coal to include any dirt there may have been in the truck previous to loading!

Again we are told that, "When cars or wagons are being dumped a scoop (size and shape are not given) may be held in the stream of falling coal." Thus we are told, "essentially" means collecting successive small increments from successive parts of the heap, and provided discrimination is used as to the relative quantities of lump

and fines, the method has every claim to accuracy."

In my opinion if an accurate result were obtained by this method it would be by accident, as when coal is running, any large lumps will most probably fall off the scoop and an undue proportion of fines will be found in the resulting sample. If coal larger than nuts or peas size is sampled, that is for anything above nuts say from $1\frac{1}{4}$ in. to as large as 18 in. diameter, we must throw this system out.

On page 2, under the sub-heading "Mine or Seam Sampling," the author of the paper again quotes Mr. Sinnatt, in what in my opinion is about the most impractical and excessively and unnecessarily expensive method of sampling a seam that I should think it would be possible to imagine, and I should like to ask the author if this has ever been carried out in practice, or is it only the result of a fertile brain and unlimited spare time? If a specimen of a seam were required for exhibition purposes overseas, where expense, etc., were no object, perhaps one might consider the matter from that point of view, but in that case I would suggest a wider section than 6 in. to show more of the coal as a set-off against the cost of admission to the exhibition.

If the author of the paper has not used a pick underground or has not tried cutting pillars out of a seam, I should strongly advise him to try and make a note of the time required to make a calorific survey of a mine by his method. I particularly mention the use of the pick by the author himself, as experience in handling the pick is a very necessary part of the operation. The usual miners' method of using a pick, or the Kafirs' for that matter, is quite unreliable. Making an accurate calorific survey of a mine requires considerable experience, and the personal factor and judgment are most important if real accuracy is the object in view, and not exhibition "pillars" packed in straw; this I think I am well able to state from a very considerable personal experience in this work.

In this country the miner mines the coal in quantity according to instructions, but only large stone or shale bands, or some continuous band not suitable as saleable coal, is left underground, the real picking or sorting taking place on the surface on a travelling belt constructed for the purpose, so that the American quotation in first paragraph on page 3 does not apply to the Transvaal. The American system published in 1918 is similar to the system published by

the South African Engineering Standards Committee in January, 1912, which I had had in use since 1908, having devised it to suit necessity, and improved it by experience. It is in use to-day with marvellously accurate results at a minimum of labour and expense. It cuts out as far as possible all unnecessary apparatus, and reduces the time required for the operation (and the cost) to a minimum without sacrificing accuracy. This I feel sure has not even been thought of, far less attempted, with the system given us by the author of the paper.

In view of the multitude of things the sampler has to take underground, I think it can be said that here it is simplicity of apparatus and a knowledge of the work, as against multiplicity of apparatus to make up for a want of knowledge of the work as shown in the paper under discussion.

It would seem that the author has written a paper on other people's experiences, or the want of it, and therefore I hope will not bear me any ill will for what I have said, and I trust that if ever he goes to England that he will read a paper on South African methods, and then I think we shall have cleared the slate, and he will have had his opportunity. There is still another little point I would like to mention as showing the impracticable ideas conveyed. I will quote from the bottom of the third column on page 3, "A second method is to place the whole of the sample in a thick canvas cloth sheet tarpaulin on which it may be crushed by means of the 'punner' or hammer." I have seen a similar method used for separating mealies from the cob by beating them inside a sack, but to break coal on canvas or tarpaulin would mean that both or one of them must be of practically no value after the operation as I leave you to guess how long the operation would continue without holes being cut in the sheeting. In this country we have to buy any canvas or tarpaulin we require.

The system of coning when quartering the coal was early discontinued for large quantities—as the work is not done in the laboratory, nor is the usual sampler of coal in this country a man trained in the laboratory. We substituted after each mixing, the following:—With samples of between 200 and 300 lbs. we lay out the coal in a square of 6 in. thick, it does not matter if it be 3 in. thick beyond the fact that it would cover too much space which is often limited; it is then quartered. The quartering is very

expeditiously and accurately done by using a cheap quartering apparatus designed by Mr. Thomas, Chief Engineer of the Wolhuter Gold Mine, which apparatus I commend to others as a time saver and insurer of accurate quartering in unskilled hands. No royalty I believe is charged for its use, only a grateful letter of acknowledgment is sometimes sent.

I will again quote, "When the weight falls to about 40 lb., samples may be sent to the laboratory or be crushed so as to completely pass through a sieve of four meshes to the linear inch when its weight may be reduced to 15 lb."

I can imagine that if all samples that were sent to the laboratory weighed 40 lb., some of these laboratories would soon be in competition on unfair lines with coal dealers who pay for their coal, besides the fact that the increased cost of storage in town would take a little of the gilt off the small amount of gingerbread allowed for the work. Surely the Home laboratories must have large spaces, cheap assistance in the way of pupils, etc., as well as get a good price for their work.

I cannot quite understand why at the bottom left of page 3, No. 6, is given as "Nitrogen percentage," No. 7, as "Ultimate analysis," giving the percentage of C, H, O, and N. If N, stands for anything else than nitrogen what is it, nitrogen having already been mentioned in No. 6, but it may be only to extend the list and make it look more important.

I would specially commend the part dealing with "associated" moisture and water of composition for discussion between the author and my learned friends the analytical chemists. It is too deep for me in its present form with the time I have at my disposal.

I am afraid the author has given us nothing new; in fact, has lightly touched on a very serious subject, almost to belittle its importance.

So far as accurate determination of moisture goes, I am in favour of the U tube absorption test with dry calcium chloride, or a similar method with sulphuric acid, to determine the error due to the oven method for each class of coal, and so standardise in every cheap method with an error factor instead of a continuous expensive method of less percentage of accuracy above the corrected one, does not warrant the increased cost where large numbers of determinations are done on a commercial basis. That I

hope will some day be the case, when the powers that be are converted to the benefits of reducing our results to a definite dry coal basis of sample and return.

With regard to the method of determination of volatile matter in a sample of coal given by the author, I can only say that the results would be quite useless to me in my work, as I make considerable use of the proximate analysis, perhaps new uses, in obtaining information not heretofore associated with chemical analyses.

I have corresponded with the American Bureau of Mines on the subject of the American method of heating the coal at a given temperature for a given period, a method which does not accurately show what the volatile contents are, but shows a result depending on the rapidity with which the coal gives up its volatile, including moisture, in a given time, which is not necessarily a true statement of the volatile contents.

The Agglutination Curve, or hit-or-miss method of determining the coking qualities of coal, does not commend itself to me since it depends on an outside factor or diluent, and since you don't know if the hit was a bull's eye, or the miss only just grazed the target; I think we might devise a better method if we had the money and time to spend on research that the people at Home seem to have.

On page 12, mention is made that "authorities" have judged "it essential that all classification of coal should be made on dry and ashless basis, or, in other words, on the pure coal substance."

It will depend a good deal for what purpose the classification is required, and how much use it is going to be when arranged. I am in agreement that all our returns of calorific value should be on the dry coal basis, the hygroscopic moisture being known; but ash is not separable from coal until burnt, a fact that must be considered when classification is considered. What is termed pure coal by the author is known here as combustible matter; pure coal to my mind is a term to be carefully used, perhaps in the future, when we know what pure coal is.

When we consider the great difference in age and composition of the coals of South Africa from those of other countries, it but emphasises my contention, that we should do our own research work, lay down our own laws, and determine our own facts, and not blindly accept the dictum of others unknown

to us, and unknowing our country, its difficulties and possibilities.

On page 16 there is reference to a sample of "slack" in which small coal when separated showed 10% of ash, and the so-called large coal contained 40% ash; this is followed by the remark, "What would be the worth of the analysis as representing the heap from which the sample had been taken if the proportion of large and small received in the laboratory had not been representative of the large and small in the heap"? Here follow a number of figures which can be read from the paper and then again I quote, "It will be seen at once that the calorific value as disclosed by the laboratory would vary tremendously in the two samples referred to." There would undoubtedly be a variation in coals having a difference of 30% ash contents, but if the sample of the whole bulk is properly taken by the method in use here and by a man who has been properly instructed, say for a couple of hours, there should result a true sample without any unnecessary separation and calculation.

The author would perhaps be surprised if he knew the system in use here, including registration and other checks on sampling coal. Anything in the way of careless sampling is soon detected, errors of labelling and numbering of samples shown up as soon as made, the percentage of errors from any source being a negligible quantity.

Without going into further detail I may say that in my opinion, the methods given by the author for sampling coal might perhaps be of use for some other purposes, but for coal in South Africa I must absolutely oppose the adoption of many of them, even in modified form, and would further warn others that there is plenty of "trouble sticking out" for whoever tries to obtain reliable results with some of these proposed methods. Most of the reliable information mentioned may be obtained from text books, but there is much of this that is not applicable to South Africa, and, further, I find no hint in the paper as to costs, or who pays. Both are important items, particularly with elaborate and expensive systems.

I would like to take this opportunity of mentioning that the success of the systems in use and mentioned above for the detection of errors, etc., is largely due to the very valuable assistance ungrudgingly given, often under trying and worrying conditions, by the analytical chemists who carry out the work of analysis and sometimes of supervision.

I have often thought that the training of

the engineer should include sufficient of the chemist's and physicist's training to enable him to appreciate and discuss the work of the chemist, and likewise that the chemist should be able to appreciate the engineer in the same way, have similar training in engineering, and then the ideal collaboration would result to the benefit of both.

I would mention, for example, the bomb calorimeter, perfect as a physical instrument of a very delicate character, but rotten as to mechanical design and operation; here it is necessary for the engineer to know the apparatus, its use and purpose, before he could design an instrument to embody the necessary strength, accessibility of all parts easy to use, and so nearly perfect in its mechanical parts, as it is in its physical principles.

I wish to anticipate a question that may be asked, that is: Why do I not read a paper on coal rather than use destructive criticism of the work of others? It is a reasonable question, and my reply to this is weak, you may perhaps think. I am the engineer to the Transvaal Coal Owners' Association, as some of you know, and in that capacity I feel that I have knowledge in trust which I could not use except in a general manner, and a general paper is not suitable to the standing of this Society, so that I may do more good as a critic inducing discussion.

I hope I shall have helped to discussion on a large scale, and to the writing of fresh papers on the subject of coal with something South African about them.

I have to propose a vote of thanks to the author of the paper for having opened up a subject that we should have opened up, and discussed ourselves, except for our retiring natures and somewhat shy dispositions. In some of this work we may claim to be pioneers; further, I think that the sale of coal on a calorific basis was better understood here than anywhere, at least up to a few years ago. I hope that shortly we shall keep ahead of the times by meeting again on a larger and more representative board, to revise, discuss, and add to our previous work.

The meeting then terminated.

Notices and Abstracts of Articles and Papers.

CHEMISTRY

A STUDY OF THE REACTIONS OF COAL SULPHUR IN THE COKING PROCESS.—"The sulphur of coal has now been definitely established to exist as pyrite

or marcasite, organic sulphur, and a rather small amount of sulphates, and accurate methods have been devised for the determination of these different forms. The behaviour of each form during destructive distillation is of importance since the reactions of the coal sulphur will determine the percentage of sulphur left in the coke and the nature and amount of sulphur compounds in the by-products.

"An apparatus was designed to heat coal in an inert atmosphere under exact temperature control, the evolved gases being passed firstly through a heated tar filter, and then through ammoniacal cadmium chloride which removed sulphuretted hydrogen, and, lastly, through alcoholic potash to absorb carbon bisulphide. The coke was ground to 100 mesh size and treated with hydrochloric acid in a stream of hydrogen—the outgoing gases being passed through ammoniacal cadmium chloride, and evolved sulphuretted hydrogen was a measure of the ferrous sulphide and pyrrhotite content of the coke.

"A sulphur analysis of the hydrochloric acid extract of the coke gave the sulphate content, while a further nitric acid extract of the residue was made to determine undecomposed pyrite.

"Sulphur in the residue was calculated by difference, and is the organic sulphur.

"The tar was tested for sulphur by the use of Esbka's method. Carbon bisulphide in the volatile matter was detected by boiling the contents of the alcohol-potash bulb, acidifying with acetic acid and adding copper acetate; the presence of a reddish brown precipitate would indicate carbon bisulphide. Eight coals were tested exhaustively, and among the changes which the sulphur compounds undergo during coking, the five following classes of reactions were established:—

1. Complete decomposition of the pyrite and marcasite to ferrous sulphide pyrrhotite and sulphuretted hydrogen.

"2. Reduction of sulphates to sulphides.

"3. Decomposition of the organic sulphur to form sulphuretted hydrogen. From one quarter to one-third of the organic sulphur is so affected in the primary decomposition, but the by product gases travelling through the coking mass increase this reaction to as much as one-half of the organic sulphur present.

"4. Decomposition of a small part of the organic sulphur to form volatile organic sulphur compounds, the greater part of which are found in the tar.

"5. Decomposition of a portion of the ferrous sulphide and pyrrhotite the sulphur apparently entering into combination with carbon.

The following table is designed to bring out the data concerning the relation of the sulphur in the coal to that in the coke:

Coal	Total S.	Pyrite S.	Pyrrhotite S.	Organic S.
Presbyterian	24.8	13.5	6.55	6.45
Washed Vandyke	7.2	2.08	1.18	1.14
East Foking	6.3	3.7	0.82	0.75
Upper Freeport	38.8	31.7	1.14	1.60
Thomas	30.6	4.04	8.54	1.52
Box Vandyke	10.1	3.9	1.86	1.50
Pittsburg	17.9	3.0	1.10	1.51

"These figures would seem to indicate that the total sulphur of the coal is the most important factor affecting the sulphur content of the coke, and that the relative amount of sulphur forms present do not affect it materially. It seems probable that the majority of coke sulphur is organic with a smaller quantity of iron sulphide present."

—ALFRED R. LOWELL, *Journ. of Ind. and Eng. Chem.*, November, 1920, Vol. 12, No. 11, p. 1069. (R. A. C.)

DETERMINATION OF MOLYBDENUM.—"The following procedures are recommended for the determination of molybdenum in ores, especially in low-grade ores and tailings from the flotation process. Volumetric method.—0.5–5.0 g. of ore, containing not more than 0.08 g. Mo, is dissolved in *aqua regia* and the solution evaporated with 20 cc. of sulphuric acid (1:1). After dilution, the solution is neutralised with ammonia, treated with 10 cc. excess, boiled, and filtered. The precipitate is washed with hot water, re-dissolved in sulphuric acid, and re-precipitated as before. The combined filtrates are neutralised with sulphuric acid, 12.5 cc. added in excess, the solution heated to 70° C. and passed through a Jones reductor 20–30 in. long, filled with amalgamated zinc. The reduced solution, which contains the molybdenum as sesquioxide, and should be of a bright green colour, is received in 50 cc. of a solution containing 50 g. of ferric ammonium sulphate, 45 g. of manganese sulphate, 87.5 cc. of syrupy phosphoric acid, and 87.5 cc. of strong sulphuric acid per litre, and the resulting colourless solution titrated with *N*/20 permanganate (1 cc.=0.0016 g. Mo). The ore may also be decomposed by fusion with six times its weight of sodium peroxide in an iron crucible, in which case the solution of the melt in water is made up to 500 cc., 250 cc. filtered through a dry paper, neutralised with sulphuric acid, 12.5 cc. excess added, and the solution boiled, reduced, and titrated as before. If the ore contains copper, arsenic, or antimony the acid solution before being passed through the reductor is treated with a few cc. of copper sulphate solution and several grms. of zinc, when part of the arsenic and antimony is evolved with the hydrogen and the remainder precipitated with the copper. The filtered solution is reduced as before. When tungsten or vanadium is present, as is usually the case with wolframite ores, the molybdenum is precipitated by hydrogen sulphide under pressure from the solution after just acidifying with sulphuric acid and adding 2 g. of tartaric acid. The sulphide is dissolved in *aqua regia* and the solution evaporated with sulphuric acid as before. Gravimetric method.—The ore is dissolved in *aqua regia* as described above and the nitric acid eliminated by evaporation with hydrochloric acid, or with 10 cc. of sulphuric acid if lead is present. The diluted solution is filtered and the filtrate boiled with an excess of ammonia, the precipitate being re-dissolved and re-precipitated with ammonia. Before filtering the solution it is treated with magnesia mixture if phosphorus is present. The combined filtrates are acidified with hydrochloric acid, 5 cc. excess added, followed by 5–10 g. of sodium acetate, and the liquid titrated hot with lead acetate solution (18 g. per litre) until a test shows no colour with tannic acid. 2 cc. excess of lead acetate is added and the liquid allowed to stand hot for 15–20 min., then filtered, and the precipitate washed with 2% ammonium acetate or nitrate solution, dried, ignited together

with the paper, and weighed as PbMoO_4 . In this method lime and sulphur do not interfere, tungsten and vanadium are removed as in the volumetric method, arsenic is removed with magnesia mixture, and copper remains in the filtrate from the lead molybdate."—J. P. BONARDI and E. P. BARRETT, *U.S. Bureau of Mines, Techn. paper* 230, 1920, —*J.S.C.I.*, 31st March, 1921, p. 183A. (A. W.)

DETERMINATION OF NITROUS FUMES IN AIR.—“A method, similar to that of Hovsøy, but applicable to both small and large amounts of nitrite or nitrous acid, is described. The liquid under examination is treated with 1–10 cc. of *p*-nitraniline solution (*p*-nitraniline, 1.5 g., concentrated hydrochloric acid, 40, water to 500 cc.) and heated at 50°C .; 1–10 cc. of *o*-naphthol solution (*o*-naphthol, 2, sodium hydroxide, 1 l., sodium acetate, 10 g., water to 500 cc.) is then added, and, after 1 hr., the orange-red precipitate is collected and weighed; 92 g. of NO_2 , or 69 g. of NaNO_2 , yields 293 g. of precipitate. The latter dissolves in sodium hydroxide solution with an intense blue-violet colour, and very small quantities may be determined colorimetrically. To determine NO_2 apart from nitrite in the fumes from fuse igniters, a definite volume of the gases may be left in contact with neutral hydrogen peroxide solution for 24 hrs., and the solution then titrated, using methyl orange as indicator; 1 cc. of *N*/10 alkali is equivalent to 0.0060 g. NO_2 . Alternatively, neutral potassium iodide solution may be used in place of the hydrogen peroxide and the liberated iodine titrated with thiosulphate solution; each cc. of *N*/10 thiosulphate solution = 0.0051 g. NO_2 .”—J. MOIR, *J.S. Afr. Assoc. Anal. Chem.*, 1921, 4, 3–7.—*J.S.C.I.*, 16th May, 1921, p. 328A. (A. W.)

GUANIDINE CARBONATE AS A STANDARD ALKALI.—“Sodium carbonate is very generally used for the preparation of standard alkali solutions, but it is open to several objections (*cf.* Rimbach, *Ber.* 26, 171; Higgins, *J.*, 1900, 958; North and Blakey, *J.*, 1905, 396).

“During the last three years guanidine carbonate has been used in this laboratory for making up standard alkali solutions, and has been found to possess certain definite advantages over sodium carbonate. Thus it can easily be freed from inorganic impurities, it contains no water of crystallisation, and, when pure, it is non-hygroscopic.

“No reference to its use as a standard reagent has been found in the literature, although Grossmann and Schuck (*Chem.-Zeit.*, 30, 1205) have suggested its determination by titration with standard acids and recommend it as a powerful alkali to precipitate zinc, etc.

“Guanidine carbonate, $[\text{NH}:(\text{NH}_2)_2]_2\text{H}_2\text{CO}_3$, is a strong “mon-acid” base; the hypothetical guanidonium hydroxide from which it is derived approximates in strength to the alkali hydroxides, and is stronger than the tetra-substituted ammonium hydroxides (Ostwald, *J. prakt. Chem.* (2), 33, 267). The heat of neutralisation of the free base is 11.12°C . per g.-mol. (Morrell and Bellars, *J. Chem. Soc.*, 1907, 1012).

“The carbonate as ordinarily prepared from guanidine thiocyanate, *i.e.*, from ammonium thiocyanate as starting material, is not to be recommended. Generally it is hygroscopic and contaminated with ammonium and potassium salts. In any case the purification is costly, and the yield of carbonate from thiocyanate, using potassium

carbonate and alcohol extraction, is only 70% (Volhard, *J. prakt. Chem.*, (2), 9, 10).

“The product made from dicyanodiamide, *i.e.*, from calcium cyanamide as raw product, is extraordinarily pure, and should be obtainable for a few shillings a pound.

“Guanidine carbonate is precipitated from its aqueous solution by addition of alcohol, and it is best to make use of this fact to obtain the analytical reagent. Two precipitations from its aqueous solution and washing with 80% alcohol yield small white crystals which after drying at 110°C ., show a purity of 100% if tested with standard acids, and can be stored in a well-stoppered bottle and used without further treatment for standard alkali for works use. Samples left covered but exposed to the atmosphere for 14 days in a warm corner of the laboratory did not gain in weight appreciably. Beautiful colourless crystals weighing up to 3 g. can be obtained by slow evaporation from water, but although they are anhydrous they would not, however, be used for analytical work, since they are liable to occlude impurities and a small quantity of water.

“Although it is generally admitted that *N*/1 solutions are not sufficiently accurate for analytical work, it is nevertheless the usual practice of acid manufacturers to sell their acids on the acidity of a weighed quantity against *N*/1 caustic soda, itself standardised against *N*/1 acid checked against *N*/1 sodium carbonate.

“Accordingly, a *N*/1 solution of guanidine carbonate (90.07 g. per litre) has been compared with *N*/1 sodium carbonate and *N*/1 potassium hydroxide (from mercuric oxide and potassium iodide). The strength of the sulphuric acid was about 0.957 *N*. The sodium carbonate was Kahlbaum’s “pro analysi” dried at 100°C . Solutions were all used at 50°C . in vessels calibrated at that temperature. The following results in g. per l. are the mean of three observations:—

	Sodium carbonate	Guanidine carbonate	Potassium hydroxide
Methyl orange ...	64.853	46.816	46.91
Congo red ...	46.67	46.76	47.1
Alizarin red ...	46.72	46.76	46.78

“The acid when standardised against caustic soda itself standardised against *N*/1 hydrochloric acid (by Gay Lussac’s method) with phenolphthalein as indicator gave a result of 46.893 g. per litre. These figures show that the testing of sulphuric acid by means of guanidine carbonate instead of sodium carbonate is accurate enough for routine works practice.

“Guanidine carbonate has also been used for the standardisation of *N*/10 sulphuric acid. Carbon dioxide was not removed, as is advisable for accurate work. The following table gives the factor of approximately *N*/10 sulphuric acid, each being the mean of three observations:—

Indicator.	Guanidine carbonate.	Sodium carbonate.
Methyl orange ...	1.0075	1.0081
Alizarin red ...	1.0049	1.0075
Congo red ...	1.0060	1.0075

“The higher figures with methyl orange are possibly due to a slight acid reaction of the carbon dioxide.

“It thus appears that guanidine carbonate should prove a satisfactory and convenient reagent for acidimetry. It merits a more minute investigation,

using more delicate indicators, such as bromothymol blue, which are now available.—The Research Laboratory, the Alby United Carbide Factories, Ltd., Dagenham."—A. H. DODD, *J.S.C.I.*, 30th April, p. 59T. (A. W.)

THE DESULPHURISING ACTION OF HYDROGEN ON COKE.—Sulphur has always been an objectionable constituent of coke, and, as the supply of low sulphur coal becomes less, the presence of more and more sulphur in metallurgical coke is a real problem. Coal washing has been resorted to in many regions where high sulphur coal is mined, but even efficient methods of washing often will not solve the problems, since this treatment removes pyrites partially but not the sulphur in organic combination.

"In most cases one-fourth to one-half of the sulphur in coal can be removed by washing.

"Many schemes for removing sulphur from coke itself have been proposed, among these being processes involving passage of gases through the coking mass in the oven, the gases, air, steam, chlorine and carbon dioxide having been used. Processes involving the addition of compounds to the coal before coking have made use of salt, sodium carbonate and manganese dioxide.

"None of the above coke desulphurising processes have ever found extensive application.

"After consideration of the reactions outlined in the previous paper, and also of the fact that the sulphur of coke may be eliminated by the action of nascent hydrogen, the author considered that hydrogen passed through the coking mass might show a material desulphurising action.

"If this were so, the process might find commercial application since the lean by-product gases produced by the carbonisation of coal contain about 50% of hydrogen. A series of experiments demonstrated that the effect of hydrogen on the removal of sulphur from coke is very noticeable. In most cases the majority of the sulphur is removed from coke in three hours at 1000° C.

"Gaseous mixtures, containing hydrogen, such as coke-oven gas, are slower in their desulphurising action, and even with a longer time of exposure would probably never give the degree of desulphurisation attained by the use of pure hydrogen. Their efficiency for the removal of sulphur from coke is high, however, and the repaving of by-product gas through the coking mass may prove of commercial value.—A. R. POWELL, *Journ. of Ind. and Eng. Chem.*, November, 1920, Vol. 12, No. 11, p. 1677. (R. A. C.)

METALLURGY

BAKING A GOLD ORE.—I have read the article on this subject in your issue of the 17th July, and write to say that while making some cyanidation experiments recently I made observations similar to those of Mr. B. L. Gardner. The ore was auriferous galena, with some pyrite, in a quartz gangue. About 40% of the gold could be amalgamated, of the remainder the galena carried three times as much as the pyrite. The leads assayed 1165 per ton. When all the ore was crushed to minus 10 mesh, with 70% of it passing through a 200 mesh screen the extraction by cyanidation in 96 hours was between 40 and 65%. If, however, the sample used in the experiment was baked so that the normal dark-grey colour was changed to a light brownish tinge, the percentage of extraction rose to 60%, and better in a period of 48 hours, with no

important increase in the cyanide or lime consumption. The heat was not high enough to roast the ore; in fact, I found that baking for two minutes was as long a period as was necessary. I take it that the heat develops cracks in the ore and permits a readier penetration of each particle by the cyanide solution. I found that, however prolonged the agitation, within reasonable limits, the tailing could not be lowered in value to less than \$2 per ton. This insoluble portion of the gold might have been contained as distinct entities in such of the grains as were unaffected by the heat, but I am inclined to believe that this residual gold is mainly in solid solution in the galena, that is to say, it forms with the galena so intimate a mixture that the solvent action of the cyanide is practically impossible. The baking process is unlikely to be an economic one on low or medium-grade ores containing, as mined, a large amount of moisture. It seems most applicable to high-grade ores. Crushing could be done in water, the slime could be filter-pressed, and the discharge baked prior to cyanidation."—P. T. BRUHL, *Min. and Scienc. Press*, 2nd October, 1920, p. 479. (C. J. G.)

"'CHLORIDE VOLATILISATION' has been successfully applied in the treatment of low-grade copper ore by the Pope-Shenon Mining Co. at its property near Salmon, Idaho. Two comparatively simple operations are involved in the treatment by which the metal in the oxidised ore is recovered in the form of high-grade bullion. The process, developed by Dr. Robert H. Bradford, consulting metallurgist for the company, is a departure from the ordinary methods of smelting. The ground ore, mixed with pulverised calcium chloride in proper proportion, is treated in an oil-fired revolving roaster in which the metal is volatilised and driven off as a fume of copper chloride. The fume is passed through a Cottrell electric treater that functions perfectly in separating the precipitated particles of copper chloride from the gaseous constituents of the smoke. The dust is collected, mixed with lime and charcoal, and fused in a melting furnace in which oil is likewise used as the fuel. The molten copper is tapped into bullion moulds as a marketable product, while the slag, which is impure calcium chloride, is crushed and reverted to the original roaster to supply the chloride for subsequent operations. Several features of the process appeal to the metallurgist. The only raw materials required are charcoal and lime, in addition to the necessary fuel oil. A unit as small as 50 tons is economically practicable; the machinery is not complicated; and the success of neither the roasting nor the fusion depends upon delicate chemical reaction or precise regulation of temperature. Sufficient bullion has been made to demonstrate the success of the process, but the most advantageous mixtures of material and exact degree of roasting for the best results are yet to be determined. The satisfactory performance of the new plant emphasises the possibilities in combining the operations of modern metallurgy in novel ways and is a credit to the ingenuity and resource of Dr. Bradford."—*Min. and Scienc. Press*, 3rd July, 1920, p. 2. (C. J. G.)

MINING

METHODS OF AUXILIARY VENTILATION.—"Metal miners too frequently place entire reliance on natural ventilation or on compressed air, and both are likely to be inefficient, dangerous, and, in the long run, costly. A compressed air blower will rarely

deliver to a working-face more than 100 to 150 cu. ft. of air per minute. The cost is 2 to 5c. per 1,000 cu. ft., and there is danger that at least occasionally the compressed air may, through defective compressing, be charged with dangerous gases. Ordinary ventilation methods by mechanical fans produce air circulation at a cost of about 2 to 5c. per 1,000 cu. ft., and, with proper supervision, will readily deliver several thousand cubic feet of air per minute to working-faces, instead of the 100 cu. ft. by compressed-air blowers. For dead-end faces of drifts, cross-cuts, raises, winzes, and shafts, small electrically-driven fans direct-connected to $\frac{1}{2}$ to 10-h.p. motors force air through canvas tubing or galvanised pipe, and readily deliver 1,000 to 5,000 cu. ft. of air per minute, or 10 to 50 times as much air as can be obtained from compressed-air blowers and at much less cost. These small fan and canvas or galvanised-pipe units not only remove fume from the face, but if operated as blowers will keep a stream of moving air at the point where the machine-man or shoveller works. In hot mines especially, the worker's comfort and efficiency are greatly improved and his health and safety assured at least as far as explosives fumes are concerned. Managers of the larger metal mines now recognise this, and many new mechanical ventilation units are found in the West."—D. HARRINGTON and B. W. DYER, *Mining and Scientific Press*, reprinted from Report of Investigations U.S. Bureau of Mines, 28th August, 1920, p. 309. (C. J. G.)

THE WORLD'S LARGEST HOISTING ENGINE.—"At the Quincy mine," Michigan, the hoisting engine which was "manufactured by Nordberg, has a winding capacity of 10,000 ft. of 1 $\frac{5}{8}$ -in. rope, reaching down an incline shaft to a vertical depth of 6,600 ft. When winding the rope down the second cone, the drum has a capacity of 13,300 ft. reaching to a vertical depth of 8,600 ft. The hoist operates in balance, raising a load of 20,000 lb. of rock per trip and is designed for a rope speed of 3,200 ft. per minute."—*Mining and Metallurgy*, October, 1920, p. 6. (C. J. G.)

MISCELLANEOUS

RESISTANCE OF ANTHRAX SPORES TO VARIOUS TREATMENTS.—"A 1.5% chlorine solution killed the spores in 8 hrs., 0.5% solution in 21 hrs. A pickle containing 0.5% of hydrochloric acid was ineffective even after 31 days, 4% hydrochloric acid solution at 37° C. killed the spores after 2 days, 2% hydrochloric acid after 6 days, 1% and 0.5% after 7 days, 0.5% formaldehyde solution killed the spores in 6 days, 5% in 5 days; 0.1% mercuric chloride solution was ineffective in 1 day, and 2% solution in 88 days. At 37° C. 0.1–5% solution of mercuric chloride killed the spores in 20–5 days."—A. MÜLLER, *Arch. Hyg.*, 1920, 89, 363–372.—*Chem. Zentr.*, 1921, 92, I., 501.—*J.S.C.I.*, 16th May, 1921, p. 319A. (A. W.)

REVIEWS

EUCALYPTS AND THEIR ESSENTIAL OILS.—"Since the time of Baron von Mueller the systematic study of the Eucalypts has been almost entirely in the hands of Baker and Smith. These authorities have departed from purely orthodox methods in classification and have founded species on a system depending not only on morphological characters,

but have called to their aid, *inter alia*, the chemical properties of the products of the trees. The system that has been adopted appears to have worked out very successfully.

"In the volume under review, which is enriched with numerous beautiful illustrations, the whole of the important Eucalypts are fully described. Information is given concerning the botanical characters of the tree, its habitat, the character of its timber, and a full account of its essential oil.

"A special chapter is devoted to a description of the principal constituents found in the Eucalyptus oils, including cineol, geraniol, the terpineols, piperitol, eudesmol, cuminal, aromadendral, and cryptal. A critical survey of the methods for the determination of cineol in eucalyptus oils is included, but the *ortho*-cresol method has, unfortunately, been published in this country just too late to be included in this survey. The authors conclude:—(1) That an accurate method for determining the amount of cineol in eucalyptus oils under all conditions has yet to be discovered; (2) that no one present method is applicable in all cases; (3) that arsenic acid is less advantageous for the purpose than phosphoric acid; (4) that the use of petroleum ether in connection with phosphoric acid is an advantage if the process be carried out in the manner suggested by the authors.

"Among other conclusions they agree with most English chemists that the resorcinol method is only of use with certain types of oil. It is stated that eudesmol occurs in both the liquid and the crystalline conditions, 'although the line of demarcation separating them is evidently slight.' The authors consider that eudesmol changes its character from crystalline to liquid, and *vice versa*. The explanations of this do not appear to be very satisfactory, and it is probable that further research may prove the existence of isomeric eudesmols, each of constant characters and existing in varying proportions naturally, so that superfusion and similar phenomena may be in question.

"Cryptal is a new aldehyde of some interest, and was obtained from two different specimens as a crystalline semicarbazone, melting at 180° C.; there appears to be no doubt of its chemical individuality. Piperitone, the 'peppermint' ketone discovered by Smith, is another very interesting constituent of certain Eucalyptus oils, and interesting speculations as to its constitution are made. It is possible that thymol, which results from the oxidation of piperitone by means of ferric chloride, may eventually be prepared in this way on a commercial scale.

"The work is very free from errors, and reflects great credit on all concerned in its production."—ERNEST J. PARRY, *J.S.C.I.*, 16th May, p. 183R. (A. W.)

Changes of Address.

AARST, F. J. VAN, *1/o* Dersley: 33, Cathcart Street, Aliwal North, C.P.

BEATY, J. W. S., *1/o* King's Hotel, Vogelfontein: St. Michael's Rectory, Vogelfontein.

PRENTICE, T. K., *1/o* Mayfair, Johannesburg: Knight Central Ltd., P.O. Box 91, Germiston.

RITCHIE, J., *1/o* Johannesburg: Transvaal Silver and Base Metals, Ltd., P.O. Argent, Transvaal.

THE JOURNAL
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Chemical, Metallurgical and Mining Society
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Proceedings

AT

**Ordinary General Meeting,
15th October. 1921.**

The Ordinary General Meeting of the Society was held in the Assembly Hall, Scientific and Technical Club, 100, Fox Street, Johannesburg, on Saturday, the 15th October, 1921, at 8 p.m., Mr. F. Wartenweiler (President) in the chair. There were also present:—

35 Members: Prof. G. A. Watermeyer, Messrs. F. W. Watson, J. R. Thurlow, H. R. Adam, Andrew King, H. S. Meyer, J. E. Thomas, John Watson, A. Whitby, H. A. White, Prof. J. A. Wilkinson, J. A. Woodburn (Members of Council), H. D. Bell, J. Q. Braidwood, Dr. W. A. Caldecott, T. N. Dewar, J. M. Dixon, Jas. Gray, E. L. Hawes, W. T. Heslop, L. D. Hingle, E. Homersham, John Innes, A. McA Johnston, W. C. Lindemann, C. A. Meiklejohn, Geo. Melvill, Dr. Jas. Moir, J. F. Pyles, J. J. R. Smythe, Prof. G. H. Stanley, W. E. Thorpe, J. T. Triggs, E. M. Weston and H. R. S. Wilkes.

3 Associates: Messrs. O. A. Gerber, F. J. Kirby-Green, and V. Power.

6 Visitors and H. A. G. Jeffreys (Secretary)

MINUTES

The Minutes of the Ordinary General Meeting, held on the 17th September, 1921, as reported in the September *Journal*, were confirmed.

NEW MEMBERS

A ballot was taken for the election of new members, and the following were declared unanimously elected:—

LOOMIS, H. J., Barclay's Buildings, Johannesburg. Gas Engineer.
MARTIN, WILLIAM, African Iron & Steel Products, Ltd., Denver, Johannesburg.

Engineer.

POWER, R. C., P.O. Box 5650, Johannesburg: Mechanical Engineer.

The Secretary announced that the following gentlemen had been admitted as Associates by the Council:—

DIERING, J. H. A., P.O. Box 105, Pilgrim's Rest: Acting Resident Manager, Vaalhoek Mine, Transvaal G.M. Estates, Ltd.

LIMEBEER, A. J., P.O. Box 809, Johannesburg: Statistician, Transvaal Chamber of Mines.

SNODGRASS, J. V., P.O. Box 1592, Johannesburg: Manufacturing Chemist.

TREGONING, A. L., 57, National Bank Buildings, Johannesburg: Secretary of Companies.

VINE, H. E. SOMERS, P.O. Box 7306, Johannesburg: Auditor.

GENERAL BUSINESS.

**RESEARCH ENDOWMENT FUND: PRESENTATION
OF MEDALS.**

The President said they had that evening the great pleasure of presenting medals for Research carried out during the past year, also during previous years. Some time ago it was suggested by the Treasurer, Mr. J. R. Thurlow, that a Research Endowment Fund should be established, and that the interest on that Fund be used in the support of Research, and that the Society should present medals annually. He (the President) would have a good deal to say about Research later on in his Presidential Address, so would not, at the present juncture, take up much of their time. Professor Wilkinson, who had always been a great enthusiast in this matter, would speak on the subject, and would also introduce the medalists.

Prof. J. A. Wilkinson said he had been asked to introduce that evening the gentlemen who had been selected by the Council to receive medals which are given under the Research Endowment Fund that had been

created during the past year. The idea of the Fund was to encourage Research in the subjects of Chemistry, Metallurgy, and Mining, with which the Society was most closely associated. The idea was that a Fund should be collected and the interest should be spent each year in giving medals for the best paper read on any of these subjects during that year. He thought the Council also had in view the fact that any paper or papers before being awarded a medal should come up to the standard required by the Council. He himself thought it would be great folly if these medals were given indiscriminately, as they were not meant to be given in that fashion, but for papers of merit, and he felt sure that the Council would always keep up a high standard in that respect. Many years ago they had a scheme whereby a bonus of £50 each went with the medal, but that system vanished quickly because the money was soon expended. Since that time nothing had been done until the Fund was re-established in its present form. A capital sum had been collected during the past year, and was now the property of the Society, and the interest only would be devoted for the granting of medals. The idea was that the medals should be granted for papers read during the year, but, as they had had no funds for some years prior to the present one, the Council decided that the papers which had been read before the Society during the years which had elapsed between the death of the former fund and the establishment of the present one should be taken into account in awarding the medals. He felt sure that the members of the Society would endorse the decisions at which the Council had arrived, namely, in presenting medals to the following gentlemen: Dr. James Moir, for Chemistry, as they were all aware of the versatility of his work, for he had contributed a large number of papers to the proceedings of the Society; to Dr. W. A. Caldicott and Mr. H. A. White, each of whom, in his respective realm of Metallurgy, had contributed papers of sterling merit. Then it was with peculiar pleasure that he had also to introduce the recipient for the Gold Medal for the best Mining paper which had been read during recent years, inasmuch as the recipient, Mr. John Innes, was one of his former pupils.

Members present knew all the gentlemen he had introduced extremely well, and therefore nothing further was necessary. He

thanked the Council and the Society for affording him the privilege and pleasure of introducing them.

The President then presented the Chemistry Medal to Dr. James Moir.

Dr. J. Moir, in responding, said he felt it was very nice of the Research Endowment Committee to have awarded him this medal, particularly as he had not been very attentive to the Society of late. However, his connection with the Society went back eighteen years, so the past could be taken to compensate for the present. It so happened that this presentation coincided with his having written his hundredth scientific paper. He had therefore been looking into statistics of his writings, and the Committee which recommended his name would be pleased to learn that this Society came first in the statistics with thirty-nine out of the hundred. He had contributed something every year since 1903 (except 1918 for some reason). He even found that in one year in particular (1909) he actually contributed six papers to this Society alone—an appalling thing to do. Since then he had been attracted to the more specialist societies of South Africa, viz., The Royal Society in Capetown, to which he had given twenty-three papers, and the Analytical Chemists, to which he had given ten. In the early days, however, this Society filled a very special place—it was not severely scientific: and gave a strong scope for controversy. The controversies of these days were really lively too—they called a spade a spade—and he was afraid he must have hurt many feelings in his first half-dozen years here—merely from youthful combativeness and joy in the battle of wits.

His first appearance before them was, as he said, in 1903, when, in discussions on papers by Mr. Cullen and by Mr. Heymann, on Miners' Phthisis, he called attention to the considerable production of poisonous gas from explosives, which appeared to have been unknown at that time in this country. Well, he saw by the Agenda that Miners' Phthisis was still under discussion. However, as he had not been doing any fresh investigations, he had nothing fresh to say, but he thought Mr. Richardson's suggestion was worthy of the attention of engineering inventors. That suggestion was to use a rotary drill made of material much harder than quartz, such as crystalline carborundum. This would not only allow of a

thorough contact of water during drilling but would probably produce a much coarser dust—and they knew that dust over eight microns in size was not injurious; it would also be more efficient and economical. The present scheme of pulverising quartz in a borehole with a tool which is not much harder than quartz was really prehistoric, if people could only see it. It was like our rude forefathers cutting down a tree with a soft copper axe.

On an occasion like the present one felt that one was using the "first personal pronoun" too often—and this was a terrible feeling in one who was brought up in that famous city Aberdeen, famous, as they all knew, for self-negation. (Laughter.) It was the result of unaccustomed conspicuousness. He assured them that although he had done this before—for this was his tenth medal—he was just as nervous as ever about it. In addition, the seriousness of the occasion was added to by the fact that it was a Gold Medal—all the previous ones having been of baser clay; so he felt just like a prize cow at the Agricultural Show, which had won the Gold Medal, though not, like the cow, on his physique. (Renewed laughter.) Therefore he hoped they would allow him to retire gracefully with many thanks.

Dr. W. A. Caldecott said he need not say that he was extremely pleased when their worthy Secretary notified him of the decision of the Council. He greatly appreciated the honour the Society had conferred upon him. He had had the honour of contributing a certain number of papers to the Society's proceedings since the first year of the Society's formation in 1894, and he had also inflicted some simple formulae upon them, though he thought that his friend, Mr. H. A. White, was much more at home in the region of higher mathematics than himself.

Mr. H. A. White, in responding, said he very much appreciated the honour that had been conferred upon him, for an honour conferred by one's fellow workers must be valued more highly than any other could possibly be. No doubt one of the objects of awarding these medals was to encourage the younger worker to come forward with his observations on some subject in which he was more or less deeply interested. It was hoped that he would be encouraged to make researches, and to put the result of these researches at the disposal of members of the Society.

Mr. John Innes expressed his pleasure at receiving the Gold Medal of the Society, and deeply appreciated the honour that had been conferred upon him. Dr. Moir had referred to the fighting spirit of the Society in the "olden days." There certainly was a good deal of opposition to the methods described in his paper, but there was no real fighting. With regard to the Konimeter, which was now standardised on the Rand Mines/Central Mining Group, it was probably only a question of months before it would be adopted throughout the Reef. For the invention of this instrument he expressed the obligations of all to Sir Robert Kotzé.

The President expressed the hope that the recipients of the Medals would value them, and that they would never be in such circumstances that they would be tempted to take advantage of the premium on gold. (Laughter.)

LECTURE ON WIRELESS TELEGRAPHY.

The President drew attention to the fact that, under the auspices of the Associated Scientific and Technical Societies of South Africa, Dr. H. J. van der Bijl, Scientific and Technical Adviser to the Union Government, would deliver an illustrated lecture entitled, "Recent Developments in Wireless Telegraphy and Telephony," on the following Monday evening, in the Assembly Hall.

In this connection the President announced that the Associated Scientific and Technical Societies were arranging for a series of lectures by prominent men, on more or less popular subjects, and trusted that all members would use their efforts to make them successful.

He also drew attention to the Cabaret to be held on the Club premises on December 31st next, which he hoped would be heartily supported.

MILL FINGER SAFETY DEVICE.

Mr. J. M. Dixon: I would like to draw the attention of mill members to a model of a safety device for use in stamp mills.

The device consists of five pronged catches hung on a bar, the whole being carried, when in use, by brackets attached to the king posts.

When a battery is hung for repairs the bar is placed in the brackets and the catches swung over each to engage a finger.

The contrivance is light, handy, and inexpensive, and has the advantage, which will be appreciated in old mills, of being elastic.

i.e., centres are not fixed. The catches can be made to fit either T iron or wooden finger posts.

The President drew attention to the

model on the table of this safety device, which he hoped would be carefully examined by those present.

THE PRESIDENTIAL ADDRESS.

By F. WARTENWEILER, A.I.M.M.

It is not uncommon for your President, in his inaugural address, to present a review of recent progress reflecting the current position of that section of the Society's activities in which his own particular interest lies. I have therefore decided to follow, in the main, in the footsteps of this accepted principle. If, at times, I tread on controversial ground it is for the purpose of inviting full discussion on such subjects as shew the trend of recent scientific thought and experience toward radical improvements or changes. I do not altogether decry verbal pyrotechnics and sensational disclosure, as these often have the power of galvanising our members into interest and action.

Basic progress in science is notably slow and by reasoned stages. Many of us, engrossed in our routine tasks and having the responsibility of maintaining the high standard of efficiency set before us, are, perhaps, barely cognisant of the slow development of the art until we pause to consider and review. It is then that evolution is revealed. With these observations I will proceed to illustrate.

UNDERGROUND FEATURES.—In dealing with the Metallurgy of the Witwatersrand it is often taken for granted that the initial steps begin after the ore has been hoisted to the surface and delivered to the reduction department. On some mines this can be accepted as the starting point for the beneficiation of the ore. On others, however, natural chemical processes, which affect the subsequent treatment, begin in the stope, the ore pass and the pump sump, and it is due to the recognition of this fundamental fact that one large group has begun ore treatment underground and has extended the responsibility and usefulness of the chemist and metallurgist. I allude to the chemical control of neutralisation of acid mine water by means of lime, the settlement of sludge, its subsequent disposal, and the

maintenance of a favourable composition of water for re-use in dust allaying, in which there are pitfalls unseen except by the trained chemist. The precipitation, from a supersaturated mine water, of the calcium sulphate formed in neutralising or its prevention by adequate dilution, cannot be ignored without the payment of the penalty, scale in pipes, or the purchase of an expensive precipitant.

The precise chemical control appeals to the economist and mine owner as a means of saving tons of steel and other corrosive material used underground, not to mention that of cyanide at the surface plant. As an example the experience of one mine may be mentioned where, by careful control, cyanide consumption has been lowered from 0.28 lb. to 0.18 lb. per ton ore treated.

Acidity in mine water has been known to be sufficiently high in some old workings to blister the flesh of men coming in contact with it, as the episode of a mine manager who had such a practical though painful demonstration. We have also heard of miners who have suffered from the burn of strong alkalinity by coming in contact with an accumulation of milk of lime in some back water underground. The one points to the moral of the usefulness of information on the degree of acidity, the other, of wastefulness of lime when not applied under precise control or at the most effective place.

The practice of underground support by means of ore packs is well known, and has been described at our meetings by several members in an interesting manner. In view of the chemical and physical alterations taking place in these packs the question arises whether such a method of mining affects the subsequent extraction of gold, and to what extent. No satisfying answer has been forthcoming, perhaps due to lack of opportunity for a definite test.

Sand filling, which has returned hundreds of thousand of tons of residue sand to the

place of origin, the stope, has found its way back to the reduction plants in small quantities, particularly on outcrop mines, where ground movements and consequent break away of sand barricades take place. The incidence of this acid material in the extraction of gold from the clean current ore is noted by reduction men to be adverse.

CRUSHING AND SORTING, operations so closely related, locally, as to be dealt with under one heading, is such an important and comprehensive subject that it could easily form the sole basis of a paper. Interest seems to have lagged of late years. Is it because the existing plants are considered capable of fulfilling all requirements from the point of view of efficient crushing, sorting, and low cost of operation? Not until you make a close study of various types of stations now in operation are you impressed with the variety of objectives originally affecting the design of each.

The early designers, in the pre-conveyor belt days, built skywards and in conjunction with rotary sorting tables, often employed crushers at the highest point of the structure for cracking large rock prior to sorting. Many of these old plants continue in operation, and excellent work can be obtained. Sorting to the extent of 16 per cent. has been carried out in a station of this type by picking out the valueless class of reef in addition to the usual quartzite and dyke waste.

We then come to the type of station employing conveyor belts, and in which sorting and crushing in two stages is practised. Although the high sorting percentage possible with such a design has fulfilled the most sanguine expectations in this direction, lack of native labour and the economic factors have usually retired it in favour of the simple straight line design now found on our later plants. Such a station with trommel washing or with washing on a sharply inclined portion of the sorting belt lends itself, by reason of simplicity, to minimum capital and running expenditure.

One of the latest plants provides for the washing of all the ore coming from the mine, including the grizzly by pass, called unsortable fines, which comprise as high a proportion of the ore milled as 40 per cent. This is an innovation and the object is three fold: first, the avoidance of sending slushy fines to the stamp mill line, the moisture from which leads to decay of timber and battery foundations, rusts steel, and indirectly causes stem and cam shaft breakage through

irregular feed; second, all material passing a $\frac{1}{2}$ -inch punched screen is sent to its most efficient grinding machine, the tube mill; third, the chemical motive, which allows thorough neutralisation with lime water of that portion of the mine delivery which benefits by such treatment. It is of interest to note that as much as 15 per cent. of the ore milled is by-passed by this method.

With the realisation of the expense of conveyor belt wear and tear, the readoption of preliminary cracking of large rock is being considered in order to reduce incidental rough usage. Also washing trommels stationed at the primary bins are favoured for the elimination of the slushy fines, so that no belt need become a conveyor of a material which, having the property of mobility, is preferably transported by the impulse of a modern centrifugal pump. The sorting percentage becomes a function of the number of native sorters and the amount of waste present. This last depending so often on underground conditions and the reef formation. It is, perhaps, not always realised that many mines, owing to peculiarities in their payable ore channel, present individual problems in sorting which must be studied separately if this important part of ore dressing is to be conducted on an intelligent and scientific basis.

Regarding crushers, which are taken so much for granted, the two standard types, jaw and gyratory, continue to hold the field. That stamping efficiency is greatly advanced by careful maintenance of their wearing parts and by close setting has always been known and has again reached the practical stage since manganese steel need no longer be devoted solely to armament purposes.

STAMPING—The Californian stamp and its first cousin, the Nissen, have survived. There are those in our Society who hold the view that these will continue to crush Witwatersrand banket ore at least during our generation. Others feel that improved modern ball or tube mill development will seal their doom as an economical stage crusher. The question is extensive in its bearings and is most important. Working experiments have recently been conducted on this very point at one of the far East mines. To what extent the crusher and the tube mill can economically encroach on the domain of the stamps, squeezing it out of existence, between their extended functions, is a point for careful trial on an extended working scale. Let us offer the columns of our

Journal, as in the past, for the discussion of developments on this subject.

It is on this mining field that the heavy gravity stamp has reached its highest state of perfection. The 1850 pound Californian stamp at the Government Areas mill crushes 28.5 tons per 24 hours through a screen aperture 0.625 of an inch square, while at New Modderfontein the 1,900 pound Nissen stamps 31.5 tons through a somewhat finer screen.

If you are statistically inclined, the size and power of the stamp mills on the Witwatersrand may be illustrated in various ways. For example: if all the 10-stamp batteries were placed adjoining they would make one continuous line extending for a distance of two and a half miles. If all the stamps were combined into one the blow of this mammoth stamp would be equivalent to a weight of 5,200 tons dropping eight inches 99 times per minute.

The roar of stamp mills since the early Californian days has followed the axe of the pioneer in many parts of the world, and whatever may be their ultimate fate, to those of us who have spent many working hours in a stamp mill, the surf-like roar of its many batteries will remain impressed in our minds as symbolical of the restlessness and untiring energy of the gold mining industry.

TUBE MILLING.—Tube milling practice nowadays appears to be rather one of detail. The tube mills are called upon to grind to a finer degree of comminution than ever, one plant delivering a final product of which 90% passes the 90 linear mesh screen. Good practice now demands a coarse feed, the new installations feeding $\frac{1}{2}$ -inch maximum size. The trials referred to previously experimented with feed as coarse as that fed to stamps.

Scoop discharges of varying effective lift with screen openings of ample size to permit free discharge of the spent pebble are generally adopted except on old plants where the use of small motors does not permit the resulting high power load. Shell liners of the Osborn and El Oro type find general favour. These are keyed and require no holding bolts. End liners are either cast or forged from discarded stamp mill shoe shanks or dies.

No recent data has been published of the merits of the short 6 ft. dia. by 16-ft. length tube in comparison with the orthodox size,

5-ft. 6-in. dia. by 22-ft. There are also a few 6-ft. dia. by 20-ft. mills in operation whose performances have yet to be compared.

Since the trials of the Giesecke ball mill, to my knowledge, no further attempts have been made with steel balls. How effective a modern large diameter ball mill would be on the banket ore leads to interesting speculation. It should be recognised, though, that this ore is one of the hardest and most abrasive known, and a steel ball which readily crushes porphyry ore may prove impotent on banket. There are undoubtedly degrees of hardness and toughness in the ore delivered to reduction plants scattered from Randfontein to Springs, and it may be no idle speculation to look forward to the discovery of an ore that will lend itself to a change in grinding medium.

AMALGAMATION.—Like taxes, the ancient amalgamation recovery method is still with us, and is responsible for from 40 to 70 per cent. of the assay value of our mill feed. While, with our system of classification, preferential amalgamation really takes place in practice, the question arises whether this could not be intensified and mechanical contrivance and concentration called in. The day of the non-amalgamating plant and the extraction of all recoverable gold by cyaniding may arrive. In fact one mine has committed itself, and elsewhere working trials having this in view have been projected and are only awaiting opportunity and adequate support. Undoubtedly the knowledge that visible coarse gold is found in certain portions of the richer mines has acted as a deterrent with responsible officials. Aside from any technical advantage, the introduction of a method which reduces or eliminates the risk of mercury poisoning would seem to have human merit.

CYANIDING AND CHEMICAL TREATMENT.—No fundamental changes have been effected in cyaniding in the last few years. Considerable experimentation, however, has been conducted quietly, resulting in gains here and there. The practicability of collecting sand and its treatment in the same tank is well established at one of the most recently erected plants. Careful classification is a corollary. The importance of close classification and the advantage of fine grinding of the pyritic portion of the ore is receiving constant attention by reduction officials.

Cyanide solution strengths have been on the down grade, and with the adoption of

de-aeration of solutions prior to precipitation they will continue on this course. The saving of cyanide and zinc resulting from this constant pressure of experimentation with lower and lower cyanide strengths and with improved precipitation technique has been considerable. On one group of mines alone it has amounted to a quarter million sterling in five years.

Precipitation has received due attention, and on some of the plants a feed rate per diem of 2.3 tons of slime solution per cubic foot of zinc shaving in extractor boxes is current practice. The Chamber of Mines financed extensive trials on the de-aeration of cyanide solution, and, resulting from these, mechanical de-aeration has been decided on at five reduction works, of which three installations are in operation. The expectation of direct and indirect economy promises to be fulfilled. Interesting details, it is hoped, will be brought forward for discussion this year.

Precipitation research has not been lacking within recent years; the margin of possible improvement, however, is small, and any new process calling for a new installation with heavy capital expenditure is severely handicapped by economic considerations.

Oxidising reagents by reason of rapidity of reaction and expense do not find favour these days. Their effect is evanescent and apt to be harmful. The economical and satisfactory supply of oxygen continues to be derived from free air. Experience with de-aeration has taught us how readily air dissolves in solution and how watchful one must be to prevent this at certain stages of the cyanide process.

Vacuum filters are now accepted by the majority as standard slime washing equipment for new plants. Their washing is controllable, depending so much less than the decantation process on ratio of dilution and on the weather. Many installations maintain a consistent daily capacity rate of 3.5 tons dry slime per foot.

Smelting and Refining.—No innovations have been introduced in recent years into refining and smelting on the individual mine. The large Refinery erected near Germiston by the Chamber of Mines for the purpose of refining the gold output of the Witwatersrand for the chloring process is about to operate and will no doubt offer a most interesting study to our technical men.

We hope to be favoured with a description of its technology in due course.

Acid treatment of the gold-zinc slime from precipitation remains general practice, although with the precipitation improvements referred to this will possibly be discontinued. Subsequent calcination and pot smelting or reverberatory lead smelting is the practice according to preference or works convenience. Small blast furnaces are found useful for smelting by-products on the larger mines. For others the Witwatersrand Co-operative Smelter, a most excellent institution, fills all requirements. The treatment by cyanide of the "black sand" or pyritic by-products from amalgamation has received attention by many of our members and is well established.

Periodically, schemes for utilising the zinc sulphate liquor, now wasted, are brought forward. Many of them are ingenious and have undoubted merit, and I confidently look forward to an economic utilisation of this liquor.

In concluding the foregoing traverse of local metallurgy, I venture to reiterate that sound development is visible, and in the words of the young assayer who found a large-looking speck of gold unweighable, is at least equivalent to "two traces."

BASE METALS: During the present slump in the sale value of base metals these have been neglected in the presence of their gigantic gold neighbour. Our Society has always been interested in the metallurgy of the baser metals, and we have had interesting papers in the past and look forward to others in the future. Not many miles from here a silver lead smelter was blown in only the other day, that of the Transvaal Silver and Base Metals Co., at Argent. Tin has been smelted for several years at the tin mines situated up-country, and that fascinating branch of metallurgy, that of copper, has been practised at Messina and the Falcon Mine with great activity throughout the war. Great developments are from all accounts taking place at the Congo copper mines in that remote and therefore mysterious region. Rhodesia boasts of a large working chrome iron deposit. Pyrite is being mined in the Lydenburg district, and, after concentration, is sold to chemical plants for both its sulphur and gold content. Considerable asbestos and mica are mined in South Africa, yet the method of selection and preparation for the foreign market, or in other words,

the ore dressing, remains a sealed book to most of us.

INDUSTRIAL CHEMISTRY.—During the latter part of the Great War, South African chemical industry received an impetus. Many chemicals were not importable and must of necessity be produced in the country. Artificial chemical fertiliser was among these. Bones suddenly loomed important in the economy of food production as potential carriers of the essential plant foods, phosphate and lime. Kraal ash deposits in the dry Karroo region were sought after for their comparatively low potash content, and bat caves and mineral phosphate deposits were prospected for with the hope of filling the gap in the supply of the necessary phosphates and nitrates. The production of fertiliser is of national importance, particularly applicable to the older districts where the chemical food capital of the soil must not be withdrawn without due replacement. The war-devastated Somme region in Northern France, in appearance not unlike a sweep of the high veld, will again bring forth its wonderful cereal crops being underlain at grass roots with calcium phosphate. The very mine craters and shell holes have scattered their phosphatic contents over the surrounding soil, replacing that taken away in the form of food.

Some of the fertiliser factories of the Union have survived foreign competition, particularly where low cost raw supplies are available. For the manufacture of super-phosphate, phosphate continues to be imported, no lime phosphate having as yet been discovered. Has the Government pushed any reconnaissance or survey in this respect? Has it found it hopeless and must our wheat production of the future lie at the mercy of imported phosphate? Has the arid coast of the mandated South-West been closely prospected for the life-giving mineral tri-calcic phosphate?

In another field of industrial chemistry, between Pretoria and Warmbaths, is situated a truly interesting deposit of carbonate of soda. It is more aptly termed a source, since the soda liquor seeps into boreholes like water into a well. A chemical industry has been developed there, employing crystallisation processes which follow modern lines and are well worthy of study.

Coal of the bituminous class, with which South Africa is plentifully blessed and which is engaging the attention of our captains of industry, is the most wonderful raw chemical

substance produced by nature. It can maintain life and civilisation, and, by the known combination of some of its elements into modern explosives and poison gas, can also deprive us of these and force mankind back to barbarism.

At near-by Witbank an experimental plant on a working scale has been in commission for a short time on waste coal, and is producing a few of the many by-products which start the ball rolling on endless organic subdivisions. The first produced are coke, road tar and creosote, the beginning of an industry of the first importance which, if developed in all its creative ramifications, can render the country, and thereby its people, inestimable service.

The ceramic industry of this district, dealing with the modest art of clay utilisation, is one of magnitude, and produces materials for our furnaces of a quality second to none in the world.

RESEARCH.—Our Society has been noted for the presentation of original papers describing the results of successful constructive researches in pure science. How often negative answers are the reward of long patient searching in laboratory and works many are too well aware. Such work, although valuable at times in a negative sense, is quietly buried in files.

Research is a tender plant and requires a congenial atmosphere. Inspiration and concentration are its companions. Surroundings, nature of colleagues, past successes, praise, sometimes condemnation, are also forces which circulate its life blood. Research is said to be the occupation of a gentleman. It is a noble calling and should, in theory, be unhampered by financial considerations. The scientist so engaged must have imagination, originality in addition to knowledge, and his mind should be free from all outside worries in order to be receptive of the smallest sign leading to actual discovery. These often hinge on the veriest trifle or on accident. However, if Goodyear, the inventor of rubber vulcanising, had not been engaged in rubber research for years, he would in all probability not have observed the peculiar effect of the heat on a mixture of rubber and sulphur, fallen by accident, on his stove and thus producing the first vulcanised rubber.

Research is often far-reaching in its indirect effect. A member of our Council made public at one of our meetings, as a result of careful research, a short method of

determination of oxygen in cyanide solution. This method has supplied a means of obtaining information about our cyanide plant solutions which has proved both instructive and useful.

Perhaps I may be permitted to indulge in a personal reminiscence while on this subject. When engaged in the early days of cyaniding with my chief, on the economic solution of the Homestake cyanide problem, to our dismay the sand charges refused to yield more than fifty per cent. of their gold content. Not until the discovery was made that although well drained most of the extraction was taking place in the top half of the charge, was any progress made. The chief then made one of those correct deductions, characteristic of his well-trained mind, that owing to the presence of a strong oxygen absorbing constituent in the ore the bottom half of the charge suffered under a deficiency of that necessary element, and that to overcome the then prohibitive expense of double treatment oxygen might be supplied by blowing air through the sand from beneath the filter mat. This proved to be sound and practically spelled success to the cyanide treatment of Homestake tailings. Although apparently a small point, in its result it has been of the utmost practical value.

THE HUMAN ELEMENT—And, gentlemen, before I close, permit me to speak briefly on the human element, a subject in which our Society has always shown interest and voiced opinions.

To my knowledge, few more elaborate ways and means for partaking in sport and recreation are offered to the employee of industrial concerns anywhere than those which are found on the mining field. With the inception of the 6-day week for reduction workers the nightmare of the seven working day week has disappeared. As a Society we continue to promote and discuss safety first and health measures, as witnessed by the symposium on prevention of miners' plagues.

As a class scientists and technical men are inarticulate, and although of no mean mentality and accustomed to the acceptance of responsibility, carry but little power and input no force into public life. Perhaps studious inclination and political disinclination are at the root of it. It is certainly to our disadvantage in these days when begotten floods and the restoration of fol-

lacious shibboleths by phrasemongers sway and govern the world. Perhaps we prefer not to mix in the poison gas of public affairs. However that may be, let us hope that our abstinence will never lead to the extinction of what we call our civilisation. It is held by thoughtful men that we have a public duty to perform and a responsibility to accept. As men trained in natural science and disciplined in the hard school of facts we are expected to possess that conception of duty and love of truth which leads to high ideals. And one of these may well be the stimulation of greater intellectual and creative interest in the every-day life of those performing the routine work of the industries and processes which we have the honour to organise and direct. Our leadership should be an inspiration to those engaged in the wide field of applied science.

We are expected by the country to blaze the trail of scientific and technical progress, not only by transplanting the knowledge and the known processes of technology to these shores, but also to create new methods and to discover fresh resources.

Prof. G. A. Watermeyer said it was his privilege to ask those present to join with him in thanking their President for the extremely valuable address he had given. It had been such an exhaustive review that one could hardly conceive of anything being left out. He had touched upon practically everything that had taken place in recent years, and the review was so complete that it must really stand as a classic. It had been extremely thoughtful. He had given them his own opinions, which they would all be glad to study at their leisure. Their President deserved their heartiest thanks.

Mr. H. A. White, in seconding, said the Society was undoubtedly to be congratulated upon the eloquent and stimulating paper that had been read to them, and it must encourage them in their future work. Their united powers should be devoted to press upon the Government the necessity for encouraging research work in every way, and paying far more attention to it than had been done in the past.

Mr. Jas. Gray also supported the vote of thanks to the President for his address.

The President briefly expressed his acknowledgments.

COAL PILLAR EXTRACTION FROM TWO SEAMS, AND SURFACE EFFECTS.

By WILLIAM TAYLOR HESLOP, M.I.M.E., F.G.S.

The following notes are mainly based on observations and experiences at St. George's Colliery, Natal:—

For the benefit of those members who are not familiar with coal mining practice it may be well at the outset to consider some of the properties and characteristics of rocks when subjected to great pressures, as in pillar extraction. We do not usually think of rocks as subjects for *bending* strains, but every miner familiar with long-wall working knows that rocks do bend, and it is the property of bending that very largely contributes to the success of any long-wall working. It is still less generally known that there are certain kinds of rock which not only bend but are elastic, that is after bending, if the stress is removed they will return to their normal position.

The other two effects of pressure that require to be borne in mind are *crushing* and *shearing*. Soft rocks such as fireclay and shales often offer very little resistance to crushing, and may—from either roof or floor of a coal seam—be crushed and squeezed out laterally into the workings of the mine. When this takes place it is known to coal miners as “creep,” and when once it commences it is very difficult to stop. A roadway may be “brushed” to give additional height, and a fortnight later the operation has to be repeated, or if left alone in the course of a few months the fireclay will be squeezed from underneath the pillars until it ultimately touches the roof of the working places.

Shearing takes place whenever the measures have support at one point, and support has been withdrawn for a sufficient distance from that point, and it constitutes a distinct break or crack in the roof. In long-wall working we largely depend on the *bend*.

Occasionally we get a further factor in the situation, that is, *hydraulic pressure*. With a certain amount of “sag” or bend in the strata space may be given for accumulation of water and the static head may be concentrated at one point in such a way that the roof must break. The average pressure of the water would, of course, be no greater

than that due to rock pressure, indeed it would be considerably less, but it may be applied actively at a point, which, had the rocks been dry, would have safely bridged over.

But in pillar extraction by far the most important principle which must be thoroughly grasped is the application of the *cantilever*. Without the cantilever support to the great overlying rock mass pillar extraction would be impossible. The most liberal of timbering in the “lifts” is altogether inadequate to support the overlying mass of strata. Were it not for the protecting cantilever the rock would shear down on to each “lift” before the coal could be extracted.

In pillar extraction the cantilever is continually protecting the miner, and the shear tendency is continually trying to break down the cantilever. If the resistance to shear is small, the cantilever will be short; if the resistance to shear is great the cantilever will be long and big.

It will be evident that the fulcrum of the cantilever must lie at or near the coal face. With hard roof, hard coal, and hard floor, the fulcrum would be very near to the edge of the coal, but with soft coal, and generally it is comparatively soft, there is a certain amount of crush, and the fulcrum of the cantilever may be a few yards distant from the coal edge—at the limit point to which the crush has extended. The same effect may take place with a soft floor, or roof subjected to crush.

In long-wall work the cantilever is being continually assisted by the bending tendency of the strata; the more flexible the rock the more chance it has to bend down, without shearing, until it comes to rest on the pack-walls. With a very hard roof which will not bend shearing action frequently takes place at the coal face, and consequently the amount of cantilever is variable, that is, it accumulates until it reaches the shearing point, and then breaks off, and commences again.

It will be obvious that the existence of the cantilever increases enormously the roof pressure on the coal face. At 1,000 feet in depth the average roof-pressure is approxi-

mately 1,000 lbs. per square inch. If the weight of only 12 yards of cantilever be distributed over a width of only one yard of coal face as fulcrum, it is conceivable that under certain conditions the roof-pressure on the coal face would amount to 13,000 lbs. per square inch, or approximately the crushing point of granite.

These preliminary observations will, I trust, help to make more intelligible some of the points involved in arriving at the method at present in vogue at St. George's Colliery for the extraction of pillars from both seams of coal.

higher working costs. Later experience also proved that the leaving of the top seam in the goaf constituted a serious danger from spontaneous combustion.

In any system of working coal which involves the total extraction of the coal seam, whether by bord and pillar, or by long-wall, certain trials are necessary to ascertain the nature and behaviour of the roof and floor. No two roofs are alike, and the characteristics of each as regards roof movement can only be determined by trial.

In the first trial a recognised British practice that has been used extensively in the

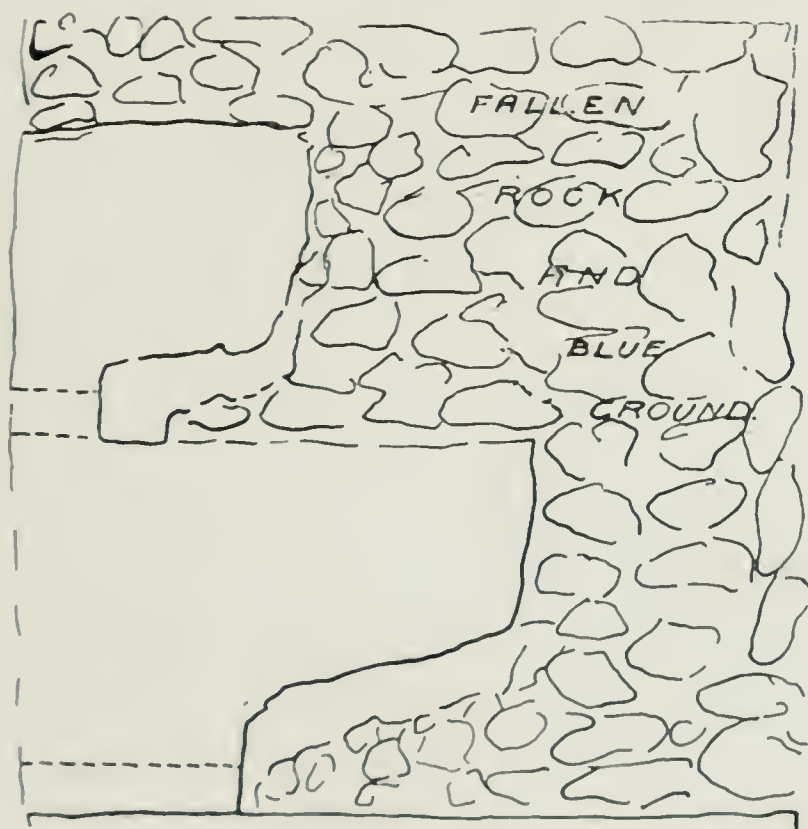


FIG. I.
The Kimberley Cantilever.

The top seam is about 4ft. thick, the bottom seam, including about 9in. of carbonaceous shale, has a total thickness of about 5ft. 6in. Between the two seams there is a bed of laminated sandstone, varying in a general way from 3ft. to 5ft. in thickness. The immediate roof of the upper seam consists of about 17ft. of shale, and the overlying strata consists of from 250ft. to 350ft. of interbedded sandstones and shales. The coal seams are lying approximately level.

The limited area of workable coal made it expedient to attempt the extraction of the maximum proportion of coal from both seams, although such extraction involved

Staffordshire coalfield was adopted. The top seam in a section of the mine about 8 acres in extent was blocked out into pillars, and the pillars totally extracted before touching the bottom seam. Care was taken to secure total extraction, and not to leave any stumps of coal which would press unequally on the lower seam. A couple of years were allowed to elapse before commencing to work in the lower seam, under the goaf. The cardinal idea of this system is to allow the roof to settle, and more or less consolidate, so that when work commences in the lower seam the roof pressure will be more or less uniform. When work

was commenced in the bottom seam the places were driven 5 yards wide, and the pillars left were 13 yards by 25 yards rectangular. The drives were all timbered, and stood very well for a distance within 60 to 80 yards of the working faces. Then as the working faces advanced further the drives behind gradually showed signs of roof pressure. The main roads were held after re-timbering, but falls took place in many of the other drives.

It will be understood that after development of the bottom seam only some four feet of laminated sandstone separated the coal

the square yard. Fortunately the roof stood well in the "lifts" and rarely gave trouble. No serious accident ever took place either in the working of the "lifts" or during the withdrawal of the timber. The liberal use of timber was an undoubted safeguard, and also a real economy, as breakage was less, and it could be used again and again. As pillar extraction proceeded the number of falls in the old drives increased, and ultimately over a portion of the area some eight or ten pillars of coal were sacrificed on account of inaccessibility because of the fallen boards.

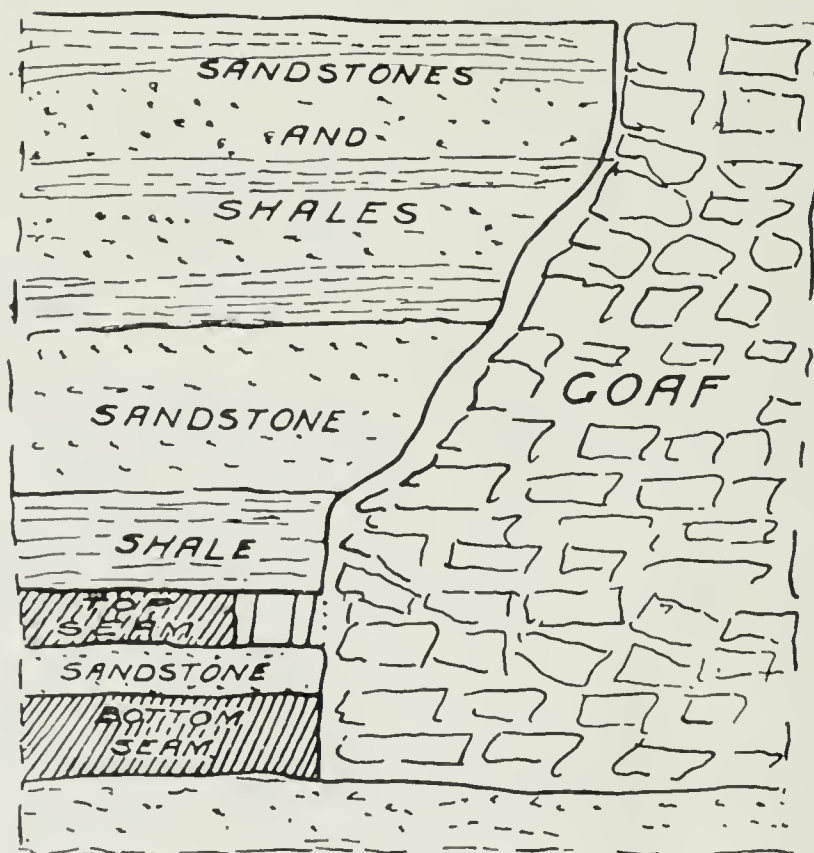


FIG. 11.
Working Top Seam Lift.

seam from some 300ft. of strata, broken up by the pillar extraction work in the upper seam.

Pillar extraction was commenced in the lower seam by taking slices of lifts 6 yards wide, and driving across the 13 yards in width of the pillar. Each lift was timbered, and as soon as completed the timber was drawn out and allowed to fall. With only four feet of solid rock between the coal working and the upper goaf fear was entertained that there would be trouble and danger in driving the "lifts," and more particularly in drawing the timber therefrom after completion. Timber was therefore used freely, averaging one five-inch stick to

The notable result of this experiment was first that the "lifts" could be easily worked, and secondly that the development drives were difficult to maintain, and were costly in timber renewals. The roof pressure came on very gradually, and the sandstones ultimately sheared close to the coal on each side of the drives.

Profiting by this experience, in the second trial the top seam was developed and the pillars extracted in a section of the mine adjoining the boundary. Then instead of developing the bottom seam as before, two drives only were driven to the boundary, underneath the top seam goaf, and then starting from the boundary drives develop-

ment was continued on a retreating system, and as soon as each drive was completed extraction of the pillars followed immediately. By this method the development drives had to stand for a much shorter period. This relieved the timbering of roads very considerably, but there was still a good deal of trouble in many of the places, particularly near the bottom seam goaf. The system also was at a disadvantage, because during the progress of the development drives going towards the boundary the two places were too far separated from the adjacent section for economical working and supervision.

parent that in order to secure a satisfactory system it would be necessary to eliminate all roads of any considerable length from underneath the top seam goaf, because of the expense of timber and maintainance. In order to do this it was necessary to cut away altogether from the old British tradition of allowing the top seam goaf ample time to settle before commencing to work the bottom seam. If the working of a bottom seam "lift" followed immediately after the extraction of the top seam "lift" just above, it was feared that the falls of stone in the top seam goaf would prove a source of

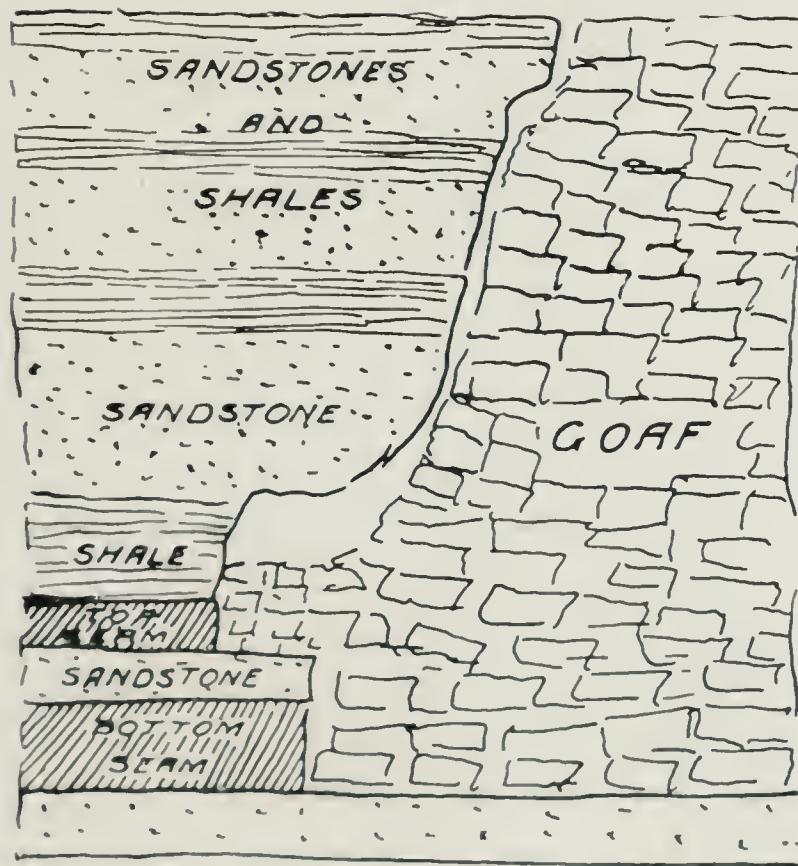


FIG. III.
Top Seam Lift Extracted and Roof Fallen.

In this experiment, as in the first, there was very little difficulty experienced in the working of the "lifts." In a few cases falls of roof exposed the goaf of the top seam, showing the roof shales fairly well compacted under the influence of pressure and moisture.

About the same time a trial was made with working the top seam by long wall, but in the subsequent extraction of the bottom seam from underneath there was considerable difficulty, as the roof pressure was concentrated on the long wall pack walls, and was therefore very uneven, and the results were unsatisfactory. It now became ap-

danger to the working of the bottom seam.

Some time before this, however, the writer had visited Kimberley and had the privilege of observing the system of working in the deep diamond mines and the practical application of the principle of the cantilever in the working of the blue ground lifts. (Fig. 1) From the experience gained there it appeared possible that the risks of working pillar extraction underneath a freshly fallen "goaf" in the top seam were considerably overrated in British practice, and that the overhang of solid rock would protect the lower seam workings from excessive and uneven goaf pressure. A trial was there-

fore made with the system, which was ultimately adopted throughout the mine.

The bottom seam was developed by blocking out into pillars 13 yards by 25 yards, the places driven being 5 yards in width. The top seam was then developed in exactly similar fashion, keeping the working places exactly over those of the bottom seam. All places were driven by line and kept strictly to the line in order to ensure the pillars of the top seam exactly overlying those of the bottom seam. All haulage roads were in the bottom seam and inclined roads were driven up into the top seam from time to time, and

solid roof proved effective in protecting the working lifts from excessive roof pressure or squeeze, and in nearly all cases with only 4 feet of sandstone between the coal and the fallen goaf the roof remained standing until the timbers of the working "lift" were withdrawn. If the roof in any "lift" commenced to "work" it was necessary to draw the timber and abandon the "lift," and on odd occasions a little coal was lost for that reason.

Coal cutting machines were generally used in the earlier stages of extraction in a new area, in the top seam "lifts," but in the

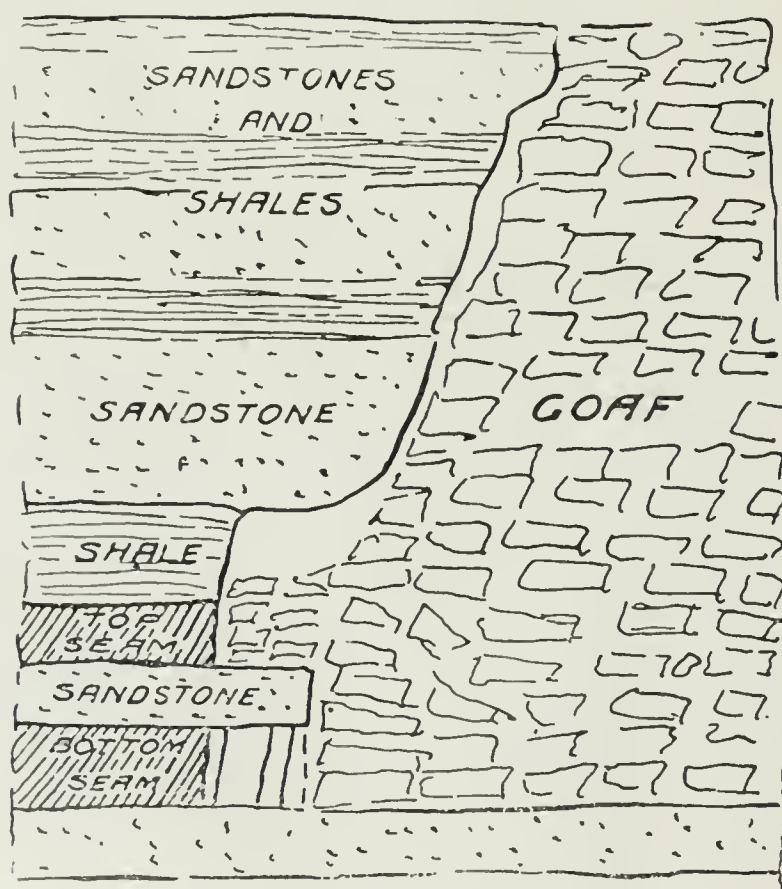


FIG. IV.
Working Bottom Seam Lift after Top Seam Lift has been taken out.

a separate set of roads maintained in the top seam. When pillar extraction was commenced a lift 6 yards wide was driven for 13 yards across the end of a top seam pillar. As soon as this was completed, the timber drawn out, and roof allowed to fall in, the corresponding "lift" in the bottom seam was driven. (Figs. II., III., IV., and V.) In this way the goaf of the top seam was never more than 11 yards (6 yards "lift" plus 5 yards bord) in advance of the bottom seam. In practice the overhang of the

bottom seam the amount of timber used prevented the application of machine-cutting. As the area of goaf increased the roof weight exerted a certain amount of crushing on the upper seam coal, and rendered coal cutters unnecessary.

In the bottom seam the absence of roof weight made the coal harder to cut, and the timbering did not leave sufficient room for the use of mechanical coal cutters. This compared unfavourably with areas where the top seam had not been worked, and bottom

seam pillars were being extracted; in which case the crushing effect of the roof was very noticeable, and the coal worked very easily. In one area bottom seam workings were carried for a distance of about 60 yards under the top seam goaf, and the results proved that after about 20 yards the roof pressure became excessive, and it was apparent that the protective effect of the roof cantilever only extended for 15 to 20 yards into the goaf.

The system of keeping the extraction lifts in the top seam leading, by not more than

Cutting out, for the time, possible losses of coal due to spontaneous combustion, some 1,300,000 tons of coal have been recovered that, by working bottom seam coal only, would have been lost. But if the coal which would have been lost because of spontaneous combustion be taken into account the advantage in coal recovery is very much greater. Allowing a ten-yard-square pillar as the minimum that could be safely left, under the conditions of depth roof and floor with no pillar extraction contemplated, a simple calculation shows that if the bottom

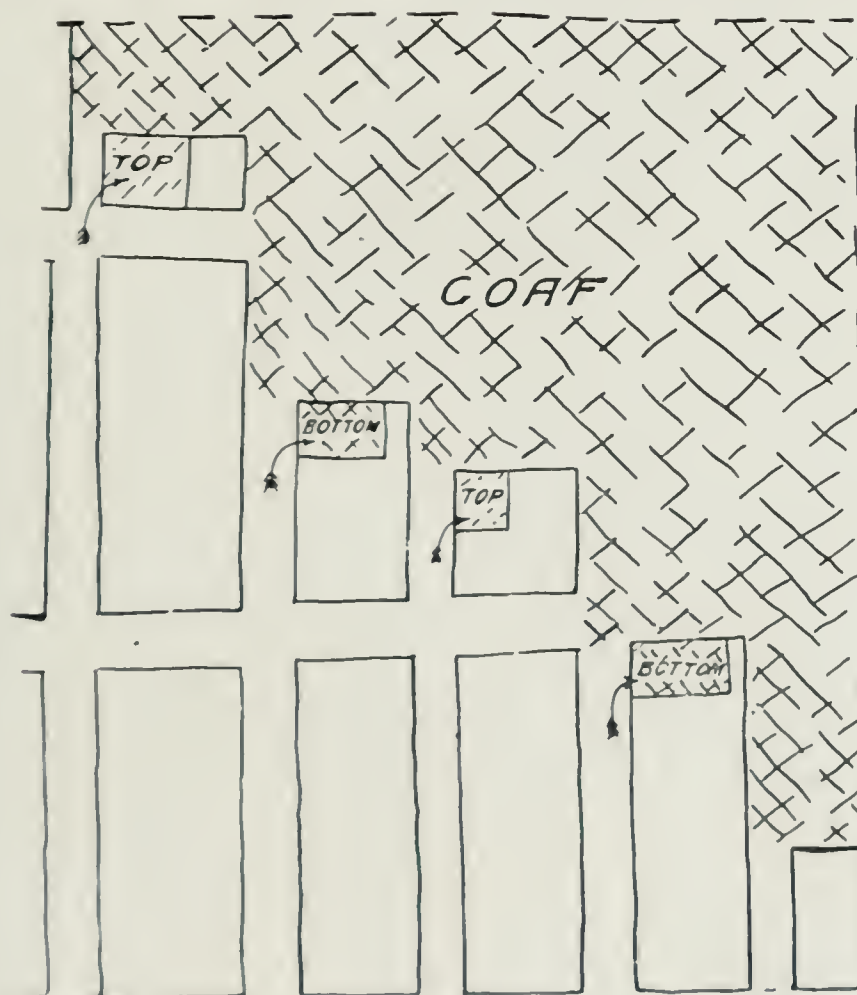


FIG. V.
Plan showing Arrangement of the Lifts.

6 to 11 yards, was therefore continued and proved eminently satisfactory.

It will be apparent that the trials described took several years to complete, and during the earlier years of the colliery's existence much of the top seam coal was sacrificed, and that no system involving higher working costs could be adopted until the company was well established on a profit earning basis. In this particular case the working of the top seam has increased the life of the mine by about 50 per cent.

seam only were worked, and the pillars left in, the percentage of extraction would be 23 per cent.

If bottom seam only were worked and the pillars extracted the extraction would be 57 per cent as against a possible extraction taking out pillars in both seams of 100 per cent.

Further, if 15 per cent be deducted for waste in working and screening the above figures would be reduced to 19.5 per cent, 42.5 per cent, and 85 per cent respectively.

The practical question of costs must always have an important bearing on the problems of alternative methods of mining. In this case the top seam was more costly to work because of less thickness, and because the coal did not part very freely from floor and roof. Where the top seam was sacrificed the bottom seam pillar extraction was the cheapest worked coal in the mine. Where the top seam pillars were extracted the bottom seam pillars did not get the benefit of roof weight, and the coal was consequently harder to cut, and in addition a small extra amount of timber was used.

In the aggregate, by working both seams the cost per ton was slightly increased, but this was much more than compensated by the increased tonnage extracted. The life of the mine was prolonged through the war period, and increased profits running into six figures were earned. That was in addition to the elimination of the dangers, loss of coal, and expense of the goaf fires.

It will be apparent that before facing a policy of total extraction both directors and manager must be prepared to make some sacrifice, at the time, for the sake of the future, and unless his board of directors were prepared to squarely face the position it would be unwise for a manager to attempt such a policy.

But when we consider the two alternatives as items of national policy the position is altogether different. Coal wasted can never be replaced. The Government is the custodian of the country's assets, and guardian to the rights and property of posterity, whilst a company director is only responsible to his shareholders.

Much has been written of late regarding the waste of coal in methods of combustion, but the first point that should be effectually dealt with is that of waste in the methods of working. It must not be assumed that the principal, or most reprehensible, waste is in Natal.

In Natal in many cases the extraction of both seams would be exceedingly difficult and costly. On the other hand pillar extraction is now general throughout the Province whereas in the Transvaal a start has yet to be made with any systematic and thorough extraction of coal pillars.

In some cases conditions will not permit of pillar extraction because of danger from water, or too close proximity to surface, or too great a thickness of coal, but in other cases the only drawback is due to the pillars

having been left too small to allow of safe and economic extraction.

From the earlier remarks regarding the excess weight, when applied on one point, due to that point being the fulcrum of a

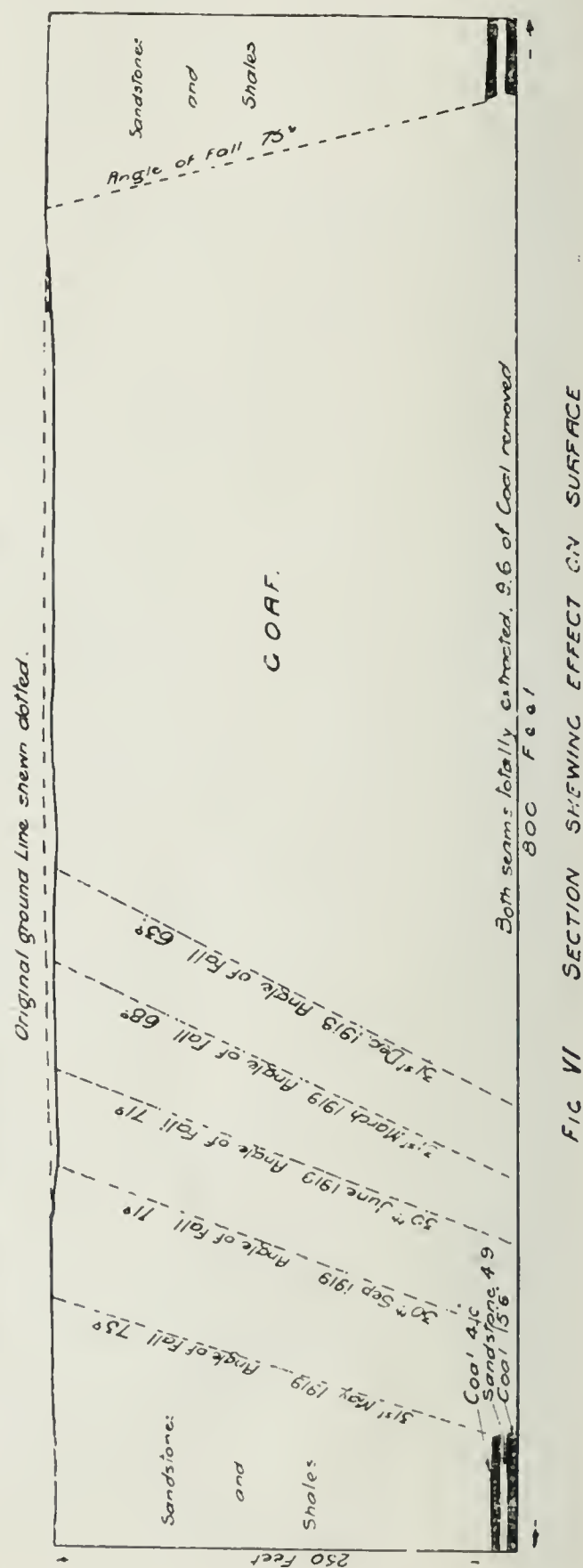


FIG VI SECTION SHOWING EFFECT ON SURFACE

cantilever, it will be readily understood that where small pillars are left these pillars might be quite adequate so long as no pillar extraction is attempted, but so soon as pillar extraction was commenced there would be excessive weight applied to the coal at the edge of the pillars bordering on the extraction area, and crushing would ensue, which might ultimately traverse the whole area of small pillars and render their extraction impracticable.

In pillar extraction the question of subsidence is of some importance, and in the above work some close observations were made.

Where the bottom seam only was extracted surface cracks showed at different points, but the amount of subsidence after taking out 5ft. 6in. of coal only amounted to a few inches. In one section where both seams were extracted surface levels were taken quarterly, and as shown in Fig. VI. the maximum subsidence was about 4ft., and surface cracks occurred at frequent intervals. As the line of extraction advanced note was kept of the relative positions of the goaf edge and the surface subsidence, and it was found that the overhang of solid rock over the goaf took an angle of about 70 per cent. from the horizontal. After the rocks had ample time to settle observation was made of subsidence around the boundaries of workings, in aggregate length exceeding 3,000 yards, and in no case did the angle of break exceed the vertical. Thus a reservation of 200ft. wide of railway pillars at a depth of 250ft. remained 200ft. wide, without subsidence at the surface, after 9ft. of coal had been totally extracted on each side. In another case where pillars were left for the protection of a building, and the bottom seam taken out all round, the rock break took the direct vertical line, but subsequently the thick bed of surface clay gradually travelled towards the goaf edge, and at a distance of 70ft. over the solid, and 350ft. above the seam, there was, in the course of several years, a drop of about 4in. and a lateral travel of about 3in.

In British practice I have observed surface depression to extend over the solid ground where the sub-surface measures are wet sand and gravel, but the risks are probably greatest with a sub-surface clay, although as the depression takes place very slowly, and extends over a very long period, the damage done to a road or railway would be much less serious than to a masonry struc-

ture. In South Africa "faults" are very uncommon in coal measures, and the risk of surface depression occurring over the solid, on account of the falls following the hade of a fault, is very small indeed.

The President said the Society was to be congratulated upon having such a paper read before it. It was particularly valuable in a time like the present, in view of the agitation for coal conservancy that had taken place.

Mr. J. Q. Braidwood, in moving a vote of thanks to Mr. Heslop, said in this part of the world a paper on Coal Mining was particularly interesting. The paper had evidently been written with full regard to detail and to fact. It was particularly interesting because there was the clear possibility that other properties which were being worked in another manner, as indicated by Mr. Heslop, might take the hint he had given.

Mr. T. N. Dewar, as an old friend of Mr. Heslop's, had much pleasure in seconding the resolution of thanks for a most interesting paper. When he was in Natal they had the same problem of two seams, and the importance of dealing with them was not realised so much as it is at the present time, and he congratulated Mr. Heslop on having the moral courage to tackle the problem as he had done, and his work, in this connection, was of national importance in dealing with a problem of so complicated a nature.

NOTES ON THE INFLUENCE OF SOLUBLE SILICA AND CALCIUM SALTS ON PRECIPITATION.

By J. HAYWARD JOHNSON.

(Printed in Journal, October, 1920.)

REPLY TO DISCUSSION

Replying to the contributions on the above paper, I am exceedingly pleased that my object has been attained in promoting a discussion and obtaining such valuable information from the members who so kindly contributed. At the same time it would have been more gratifying if greater interest had been manifested by more of my fellow-examiners who had experienced trouble with precipitation and, as I hoped, would have enumerated their remedies and thereby provoked a greater discussion. Contributions

by the users of zinc dust would also have been highly interesting, especially as regards the higher strength of alkalinity mentioned by Mr. Thurlow.

Mr. White's contribution was most interesting, and there is no doubt that his contention to destroy as much as possible the sulphur contents of the ore before its removal from the mine is striking at the root of a great source of the trouble. Unfortunately the preparatory treatment of the ore underground is very often neglected or the cost is often considered too great for the immediate department concerned and the recovery of the precious metal has to suffer. It would be of great value if Mr. White gave more details of his experiments in this subject. The thanks of the Society are due to Mr. H. R. Adam for his contribution and the experiments he carried out, which confirmed by laboratory work the results found in practice. His deduction from the results of his experiments give one considerable food for thought, and it certainly would give very valuable information and help if his suggestions contained in the last paragraph but two of his contribution could be further investigated. It has often been remarked that when poor precipitation is occurring, although the gold-bearing solution is passing through a number of compartments filled with zinc, very little of the gold not precipitated by the first and second compartments is recovered on the succeeding ones, which, I think, agrees with his suggestion "that there may be other causes of poor precipitation than the mere reduction of precipitation surface."

Mr. C. Toombs must be especially thanked for his very able contribution. Had it been read as an original paper it would, no doubt, have provoked considerable discussion, and I am sure members will be interested and anxious to hear the results of his further investigations.

Regarding calcium sulphate, which is present to a very large extent in all reduction plant waters, both Mr. Fred Watson and Mr. Toombs mention the use of sodium carbonate to reduce CaSO_4 , but, unfortunately it is expensive, and further there is always the likelihood of the precipitation of calcium carbonate on the zinc (as mentioned by Mr. Toombs), especially where solutions are heated prior to precipitation. I believe the late Mr. Torrenti advocated the use of barium hydroxide to reduce both these lime salts, but again the expense was

prohibitive. I believe barium has been found in the Union of S.A., and it may be possible to produce the hydroxide at a reasonable cost, thereby making it available for use. It is far more beneficial than sodium carbonate as it precipitates both the sulphur and carbon contents as barium sulphate and barium carbonate, which are practically insoluble in water and would therefore be innocuous.

TREATMENT OF ANTIMONIAL GOLD ORE AT THE GLOBE AND PHOENIX GOLD MINE, SOUTHERN RHODESIA.

By V. E. ROBINSON.

(*Printed in Journal, January, 1921.*)

REPLY TO DISCUSSION.

Owing to the very limited discussion on my paper I have little further to add.

In reply to Mr. G. W. Dimond, I would like to state that the only place where stibnite is removed is from the sorting belt. The small amount of concentrate obtained from the canvas strakes is returned to the mill circuit after treatment, so that the amount of stibnite sent to the cyanide plant is the same as that crushed in the battery. Marcasite is not present in the ore.

OCCURRENCES OF FIREDAMP ON THE FAR EAST RAND.

By T. N. DEWAR.

(*Printed in Journal, February, 1921.*)

REPLY TO DISCUSSION.

The discussion has not been lengthy, but several points of interest have been brought forward.

Mr. C. J. Gray, in his remarks, refers to the occurrence of firedamp in the Simmer Deep and gives a valuable analysis. The location of this mine so many miles west of the area previously described seems to point to the origin of the gas being in the lower shales, for there are no overlying coal measures. The similarity of the occurrences at Rand Collieries and Cinderella with those described in the paper is obvious, as in each case the gas issues with water from a fault in the face of a raise. The writer is in-

debted to Messrs. Gray and Fairhurst for the details given. Major Trevor contributes a useful note about the firedamp found at Gruisfontein No. 48 at Devon. The percentage of hydrogen is very high, and according to Mr. Cunningham Craig had its source in the coal measures, the dolerite sill passed through in the borehole acting as a cover similar to the sills found in the Hattings Spruit and Dannhauser districts in Natal. It is evident that the few analyses made of firedamp occurring in gold mines do not give any clue as to the origin of the gas.

Mr. John Watson quotes some interesting figures about firedamp in and under the salt deposits at Middlesbrough, England.

The writer wishes to thank those who have contributed to the discussion. If further data should be available on a future occasion he will have pleasure in putting the facts before members of the Society.

METHODS USED IN THE DETECTION AND INVESTIGATION OF VITAMINES

By E. MARION DELF, B.A., D.Sc. (Lond.),
F.L.S.

(Printed in Journal, April, 1921.)

DISCUSSION

Mr. H. J. Ireland : I have rarely read a paper containing more interesting and valuable information than that by Dr. Delf to this Society. The problem of human diet does not seem to have received in the past the attention of medical and scientific men that it should have had, partly, no doubt, due to the great complexity of the problem and the great variety of individual conditions. For many years we have applied thoroughly scientific methods to increase the efficiency of all kinds of machines: progress was made by farmers and owners of valuable horses study carefully the best diet for their animals, but the efficiency of the human race is still left very much to chance, especially in matters of diet. Even so recently as the later years of the War the Government advisers who wrote pamphlets to instruct the people in economical methods of using food, based their comparison of food values chiefly

on its calorific value; so much were calories in evidence that a scientific friend facetiously remarked to me, "Why not drink a pint of paraffin oil?"

In view of these mistakes in the past it is refreshing to read Dr. Delf's paper, which is so full of scientific facts and vital information.

The methods used for the investigation of vitamins are particularly interesting and something of a revelation to me, though I have been interested in the subject for some years and read several articles on it. A point of considerable practical importance mentioned by Dr. Delf is the destruction of vitamins, particularly the antiscorbutic, in cooking. This point is elaborated in an article by Dr. Delf in a recent issue of "Science Progress" (April, 1921), where also I observed the interesting statement that in a vegetable like the cabbage the antiscorbutic vitamin is found in the outer green leaves, but is practically non-existent in the white heart. I suppose the sun's rays are a factor in producing this vitamin. In connection with the cooking of foods, about twenty years ago I read some articles which advocated the eating of fruit and vegetables raw, the theory advanced being that the vital energy of the uncooked food was transferred to the person who ate it. Probably these advocates had some basis for their opinions in practical experience, though their explanation was no doubt unscientific. One finds a great similarity in the precepts contained in a recent book by Dr. A. White-Robertson called "Electro Pathology," where the author advocates the eating of "quick" foods, i.e., foods which are quite fresh and uncooked; the reason given in this case is that when animal or vegetable foods become stale or cooked the cells lose their electrical properties and deteriorate. He seems to connect in some way the properties of the vitamins with electrical and electro-chemical properties of the food cells and the cells of the body which ingests it.

I have the impression from some articles which I have read, but unfortunately have no notes of, that where the diet consists of large quantities of carbohydrates, there is a greater tendency to obesity and rheumatism. I would like to ask Dr. Delf if this is so.

I trust that such information as Dr. Delf has given us will soon be incorporated into the lessons on "Domestic Economy," "Cooking," "Housewifery," etc., in schools and training institutes, and that it will have a

profound effect upon the diet of our Hospitals, Sanatoria, and Public Institutions where the diet, though excellent in many respects, is usually sadly lacking in foods containing the necessary vitamins and organic salts.

I trust also that the subject of the vitamins will not become merely another medical fad, be run to death, and then be forgotten for a generation. It seems to me there is a danger of it being divorced from the general subject of dietetics, interest in it being developed to the exclusion of other factors, such as the need of certain salts, etc. I have an instance in mind. A person may have a disease or diseases which tend to decalcify the blood; this person may at the same time require food containing a good deal of antiscorbutic vitamin, and for this reason a liberal supply of lemon juice may be prescribed, with disastrous results. The subject of dietetics, perhaps more than any other, should be "seen steadily and seen whole."

The meeting then terminated.

Contributions and Correspondence.

WASTE ROCK IN ORE MILLED.

By W. A. CALDECOTT, D.Sc.

From the mining and sorting aspect the subject of waste rock has been discussed in past years by various members of this Society, and notably among others by the late Wager Bradford.¹ In this short note, however, I merely propose to submit a few observations upon the effect waste rock produces in practice upon the capital and operating cost of ore treatment plant, and upon the methods employed therein.

In considering this subject it is obviously of the first importance to be able to readily determine with approximate accuracy the percentage of waste rock in the mill ore feed or screen sample. Apparently the simplest method of ascertaining this is to determine the relative amounts of some common constituent, which exists in different proportions in the clean reef, waste and current screen sample, and which by a simple calculation afford the required figures. For this purpose in the first instance Messrs. Jolly and Guthrie kindly carried out for me a number of determinations of the amounts of

silica in the above materials, but the high silica content of quartzite waste precluded a satisfactory differentiation between quartzite and clean reef. Alumina was considered but not proceeded with, as being inapplicable to quartzite and involving a somewhat laborious analysis. Mr. A. McA. Johnston made relative sulphur determinations, from which the pyrite could be calculated, and this proved more satisfactory, but finally gold was adopted as the basic factor on account of much assay data being regularly available on every mine as to reef, waste and screen values, without any additional analytical operations.

The formulae, based on assay values, for calculating the relative amounts of clean reef and clean waste in the ore milled are derived as follows:—

Since $100 \times \text{A. V. Screen Sample}$
 $(\text{Percentage of Reef} \times \text{A. V. Reef}) + (\text{Percentage of Waste} \times \text{A. V. Waste})$

Then,

$$(a) \text{ Percentage of Reef} = \frac{100 (\text{A. V. Screen} - \text{A. V. Waste})}{\text{A. V. Reef} - \text{A. V. Waste}}$$

$$(b) \text{ Percentage of Waste} = \frac{100 (\text{A. V. Reef} - \text{A. V. Screen})}{\text{A. V. Reef} - \text{A. V. Waste}}$$

$$(c) \text{ Tons of waste milled per ton of reef} = \frac{\text{A. V. Reef} - \text{A. V. Screen}}{\text{A. V. Screen} - \text{A. V. Waste}}$$

Examples,

$$(a) \text{ Percentage of Reef} = \frac{100 (10 \text{ dwt.} - 1 \text{ dwt.})}{28 \text{ dwt.} - 1 \text{ dwt.}} = 33.3 \%$$

$$(b) \text{ Percentage of Waste} = \frac{100 (28 \text{ dwt.} - 10 \text{ dwt.})}{28 \text{ dwt.} - 1 \text{ dwt.}} = 66.7 \%$$

$$(c) \text{ Tons of waste milled per ton of reef} = \frac{28 \text{ dwt.} - 10 \text{ dwt.}}{10 \text{ dwt.} - 1 \text{ dwt.}} = 2 \text{ tons.}$$

It does not appear usual for the published reports of gold mining companies to state the average value of the clean reef in ore reserves, except for development records, but merely to give the average value over a given stoping width or reef channel. Hence an assumed illustration has been given as above, in which case two-thirds of the total tonnage mined would be a source of loss rather than of profit through the cost of underground and surface operations, besides involving much capital expenditure on plant and equipment. It is, of course, obvious that the ideal of mining and milling clean reef only is impracticable, and the degree of approach to this ideal is mainly in the hands of the mining man, who can best determine whether any modification of present mining

¹ Proc. S.A. Association of Engineers, Vol. IX., Sept. 30, 1903, pp. 61-86. See also C. O. Schmitt, this Journal, p. 464, Vol. XI., April, 1911; H. M. Thomas, this Journal, p. 140, Vol. XI., Sept., 1910; and C. E. Meyer, this Journal, p. 49, Vol. XII., August, 1911.

practice towards the desired end is possible. Surface sorting is not practised upon some half of the mixture of reef and waste hoisted owing to its passing the grizzlies as "fines," so that any radical improvement appears to depend upon the application of mining methods which would reduce the percentage of waste rock mined and mixed with the reef, and thus facilitate the most efficient and profitable ore treatment.

Reverting to the specific example given above, and assuming 95 per cent. extraction for the 10 dwt. mill ore feed, the total residue after cyaniding would be 0.5 dwt. per ton. As, however, it is assumed that two-thirds of the total tonnage milled is waste, the residue from the clean reef would be about 1.3 dwt., which may be considered to be considerably above the economic limit of extraction. Assuming that the gold in the reef were sufficiently exposed by finer crushing to yield a residue of half the above amount, or 0.65 dwt. per ton, the net result would be that about 2.9 worth more gold at mint par per ton of reef would be recovered. When the waste is largely slate as on the Far East Rand, the readiness with which it is crushed by stamps and tube-mills produces a marked effect on stamp and tube-mill duties, and is liable to obscure the behaviour of the rich banket reef proper, besides in some cases overloading the ore treatment plant to the detriment of the adequate treatment of the really valuable ore. Apart from its effect on the economic limit of crushing, the most favourable condition of crushing waste unavoidably included in the ore hoisted is when simple crushing and treatment plant already exists, so that dealing with the whole would yield some gold and save sorting cost.

It is obvious from the equation above that the screen value of the ore milled, including tube-mill pebbles is as much affected by the percentage of waste included in the screen sample as by the gold content of the reef mined. The usual basis of comparing working cost per ton of ore crushed is an imperfect guide to maximum profit, as it does not reflect unfavourably any excess of waste rock milled, especially with rich reefs. A basis such as working costs per ton of actual reef crushed might be preferable, as at present it is possible that a company's total profit may be greater with higher working costs per ton crushed on a lower ore tonnage of higher value, than with lower costs per ton on lower grade mill ore feed.

THE SOCIETY'S ROLL OF HONOUR.

THE GREAT WAR, 1914-1919.

Supplementary List of Members and Associates on Active Service.

(First List printed in *Journal*, June, 1921.)

MCCORMICK, A. R., Machine Gun Section, 9th S.A. Infantry.
MARTIN, H. ROSE, S.A. Medical Corps.
PULFORD, A. E., 1st S.A. Horse.
SOUTHWELL, BAILEY, Lieut., R.E.
TAYLER, W. A. C., Capt., Northumberland Fusiliers.
VAIL, R. R.,
WELLS, E. F. V., Lieut., 300th Field Co., R.E.
WILLCOX, A., Capt., R.F.A.

Notices and Abstracts of Articles and Papers.

CHEMISTRY

ANALYSIS OF BABBIT METAL.—"One g. of filings is dissolved in 35 c.c. of strong sulphuric acid. After cooling, 5 c.c. of strong hydrochloric acid and 150 c.c. of water are added and, after standing for 1 hr., the lead sulphate is collected in a Gooch crucible, washed with dilute sulphuric acid, then with water, dried, ignited at a dull red heat for $\frac{1}{2}$ hr., and weighed. The antimony in the filtrate is determined by titration with potassium bromate, using methyl orange as indicator. The titrated solution is reduced by boiling for 20 min. with 0.5 g. of antimony and 40 c.c. of strong hydrochloric acid, cooled in a current of carbon dioxide, and the tin titrated with the same bromate solution, using potassium iodide and starch as indicator. The reduction may also be effected by adding 9 g. of zinc and 40 c.c. of hydrochloric acid, 5 c.c. at a time, while passing carbon dioxide. When all the metal is dissolved, the solution is titrated as before."—H. C. BOEHMER, J. R. GORDON and C. W. SIMMONS, *Canad. Chem. J.*, 1920, 1, 171-173, *J.S.C.I.*, January 15, 1921, p. 11v. (A.W.)

VOLUMETRIC ESTIMATION OF POTASSIUM AND ITS APPLICATION TO THE ANALYSIS OF FERTILISERS.—"25 c.c. of a 2% potassium chloride or sulphate solution, equivalent to 1.26 or 1.08% K₂O, is made up to 150-200 c.c. in an Erlenmeyer flask, the liquid being then treated, slowly and with stirring, with 50 c.c. of 2N tartaric acid solution and 25 c.c. of N/2 sodium hydroxide solution. The flask is shaken for 5 min., 25 c.c. of 96% alcohol being added gradually during the shaking. After standing for 6-8 hrs., the clear liquid is filtered through a 9 cm. barium sulphate filter paper and the precipitate washed 9 times by decantation with neutral 96% alcohol. The filter paper is removed from the funnel used to detach any particles of precipitate from the rod, and then introduced into the precipitation vessel. A N/10 solution of sodium hydroxide in 96% alcohol is added until the contents of the vessel become alkaline to phenolphthalein. The pink colour of the liquid should not disappear within

5 mins., at the end of which time the precipitate is dissolved in aqueous N/10 sodium hydroxide solution, the excess of which is determined by titration with N/10 hydrochloric acid. Multiplication by 0.00471 of the number of c.c. of sodium hydroxide required to dissolve the bi-tartrate gives directly the amount of K_2O present. With commercial potassium chloride and sulphate this method gives good results."—G. AJON, *Giorn. Chim. Ind. Appl.*, 1920, 2, 422—426, *J.S.C.I.*, January 15, 1921, p. 21A. (A.W.)

SEPARATION OF METALS OF THE SECOND GROUP.—"The mixed sulphides are heated with ammonium carbonate solution, and filtered: the arsenic alone is dissolved. The precipitate is then dissolved in hydrochloric acid with the addition of potassium chlorate, the solution diluted, cooled, and filtered to remove the greater part of the lead chloride. The filtrate is neutralised with sodium carbonate, sodium hydroxide is added, the mixture boiled, and filtered. Mercury, bismuth, copper, and cadmium remain in the insoluble precipitate, whilst tin, antimony, and the remainder of the lead pass into the filtrate. The precipitate is dissolved in hydrochloric acid and the solution rendered ammoniacal: mercury and bismuth are precipitated and these two metals are then separated and identified by the usual methods and tests, as are also the lead, tin, and antimony."—G. G. LONGINESCU and G. P. THEODORESCU, *Bul. Sci. Acad. Roumaine*, 1920, 6, 159—164, June 15, 1921, p. 416A. (A.W.)

METHOD FOR RAPID ANALYSIS OF GRAPHITE.—"The following method is used at the Pittsburgh Laboratory of the U.S. Bureau of Mines:—If much gangue is present the sample is ground to pass through a 60-mesh sieve. Moisture is determined by heating 1 g. in a weighed platinum or porcelain crucible, $\frac{3}{8}$ in. deep by $1\frac{1}{4}$ in. wide, for 1 hr. at $105^\circ C$. The crucible is cooled in a desiccator over sulphuric acid and the loss of weight noted. Volatile matter is determined by heating the dry graphite for 3 mins. in a muffle furnace at $800^\circ C$, cooling as before, and noting the loss of weight. Ash is determined by heating the non-volatile residue at $800^\circ C$ until all the graphite is burned away. Graphitic carbon is taken as the difference between the sum of the percentages of moisture, ash, and volatile matter and 100. Graphitic carbon in an ore is determined by heating 0.2–1.0 g. in a 100 c.c. evaporating dish with 25 c.c. of hydrochloric acid (1:1) on a hot plate for 15 min., filtering the residue with hot water. The filter and residue are transferred to a porcelain or platinum boat, dried on a hot plate, transferred to a combustion tube (containing fused lead chromate to retain any sulphur present), and burned in a stream of oxygen. The carbon dioxide formed is passed into a weighed potash bulb containing 20% potassium hydroxide solution and weighed. Graphitic carbon is determined in a concentrate by placing 0.2–0.5 g. of the sample in a small Erlenmeyer flask, adding about 25 c.c. of ether, corking loosely, and allowing to stand for $\frac{1}{2}$ hr., shaking at intervals. The mixture is filtered through ignited asbestos, the residue washed with alcohol and distilled water, then treated with acid to remove carbonates,

and the determination continued as described for ores."—G. B. TAYLOR and W. A. SELVIG, *U.S. Bureau of Mines, Bull.* 112, 1920, 43—45, *J.S.C.I.*, February 15, 1921, p. 79A. (A.W.)

GRAVIMETRIC DETERMINATION OF BISMUTH AS PHOSPHATE.—"The cold bismuth solution, containing nitric acid but no chlorides, is treated with ammonia until a slight permanent precipitate is obtained; 2 c.c. of concentrated nitric acid is then added, the solution boiled, and 10% diammonium phosphate solution is added slowly. About 40 c.c. of the phosphate solution is required for 0.2 g. of bismuth, 60 c.c. for 0.4–0.5 g. The mixture is diluted to 100 c.c. with boiling water, the precipitate collected after 15 mins., washed with hot 3% ammonium nitrate solution containing a few drops of nitric acid per litre, dried, and ignited gently. The weight of $BiPO_4 \times 0.6865$ gives the weight of bismuth. The method may be applied to the analysis of ores: the bismuth is separated from lead by precipitation with iron wire (*cf.* J., 1900, 389), copper, arsenic, and antimony are separated by extraction of the sulphides with sodium cyanide and sulphide, and the bismuth sulphide is converted into phosphate.—W. R. SCHOELLER and E. F. WATERHOUSE, *Analyst*, 1920, 45, 435—439, *J.S.C.I.*, January 31, 1921, p. 64A. (A.W.)

ACTION OF LIME ON GREENSAND.—"In the last few years a great deal of work has been done on the extraction of potash from various minerals, such as feldspar, leucite, mine tailings, greensand or glauconite, etc. For the purpose of liberating the potash, treatment with lime or with a mixture containing lime has been employed rather extensively. The author describes the process used at a small manufacturing plant utilizing greensand. He also describes research conducted. The process in outline consists in heating a slurry made from 1 part of finely ground greensand, 1 part of quicklime and 5 parts of water, in a digester for about 1 hour at a temperature around $170^\circ F$, and under sufficient pressure to keep the water in the liquid phase or at about 500 lb. pressure.

"The chief reaction which takes place is that of the lime upon the greensand, which liberates the potash in the form of a very pure caustic potash and produces a material high in lime content possessing cementitious and liming properties.

"An analysis of typical greensand is given:

Silica (SiO_2)	... ..	49.8 %
Alumina (Al_2O_3)	... ..	9.8 %
Iron (Fe_2O_3)	... ..	18.0 %
Lime (CaO)	... ..	0.9 %
Magnesia (MgO)	... ..	7.7 %
Potash (K_2O)	... ..	7.4 %
Soda (Na_2O)	... ..	0.4 %
Sulphuric Acid (SO_3)	...	0.21%
Phosphoric Acid (P_2O_5)	..	0.25%
Loss on ignition	... ..	5.6 %

"The addition of various salts such as sodium nitrate and calcium chloride are recommended for the purpose of accelerating the reaction and

to convert the KOH into other potassium compounds."—R. NORRIS SHEREVE, *Journal of Ind. and Engineering Chemistry*, August, 1921, p. 693. (F.W.)

CHEMISTRY IN RELATION TO THE FUTURE SUPPLY OF LIQUID FUEL.—"The author comments upon the future shortage of motor fuel from subterranean sources and states that the supply will have to come from a vegetable and replaceable source such as cellulose. At present the manufacture of alcohol from waste wood products by the acid process is a practical process, but does not produce a high efficiency yield or a cheap fuel. To fulfil this desideratum, chemical processes carried out by micro-organisms are suggested. Boulard in France has recently investigated with success the production of alcohol from starch by the action of certain alcohol-producing fungi. By the action of these new agents it is claimed starch may be converted directly into alcohol, although in practice it has been found better to use the fungi for converting the starch into sugar and then to ferment the latter with yeast. Much higher yields are claimed than where the saccharification is effected by acids or by malt.

"Pringsheim has been able to show that there is an analogy between the fermentation of certain carbohydrates such as maltose, cane sugar, starch, dextrines, etc., and that of cellulose. In the former cases fermentation takes place in two stages in which two different groups of ferments play an active role. These are the "hydrolytic" and fermenting types, respectively. The former bring about the hydrolytic conversion of the maltose, starch, dextrines, etc., into glucose, while the latter induce fermentation of this with formation of alcohol. Similarly under the action of certain ferments, associated with specific micro-organisms found in horse manure, river mud, etc., cellulose is converted into glucose. The first change is brought about by the action of the hydrolytic ferment "cellulose" which converts the cellulose into cellobiose. Under the action of the second ferment "cellobiase," the cellobiose is converted into glucose."—HAROLD HINBERT, *Journ. of Industrial and Engineering Chemistry*, September, 1921, p. 841. (F.W.)

SALT MANUFACTURE IN MICHIGAN.—"The main bed of the salt formation is usually pure enough to work into high grade salt with a simple preliminary treatment. Since the natural deposit is rock salt, an artificial brine has to be made by pumping river water down the bore hole leading to the deposits. A typical bore hole consists of 8 inch, then 6½ inch casing to the first salt stratum at a depth of 750 feet. Thence the bore hole passes through alternate strata of salt and limestone to a depth of 1,500 feet. In passing through the salt no casing is used. A central line of tubing goes to the bottom of the well. Wells are usually supplied with descending water through the annular space between the central tubing and the walls of the bore. If the cavity at the bottom of the well is closed, no air lift need be used and the pump which delivers water furnishes pressure for raising brine. In cases where two or more wells become connected at

the bottom the water may be pumped into one well and brine obtained from the other. At one plant it was estimated that the cavity was so large that three years elapsed between pumping in water and receiving the same water as brine.

"The brines are so pure that the usual preliminary treatment is merely settling. There is an odor of hydrogen sulphide in the brine as it comes from the wells. There is little or no iron present. From the wells the brine, which is a saturated solution, passes to storage tanks, where lime is sometimes added; thence to grainers or crystallizers. The storage tanks are made of timber held together by pins and wedges, no iron entering into the construction. The usual form of grainer is a steel trough 150 ft. long, 10 to 15 ft. wide and 22 in. deep. In it are hung steam pipes and brine is evaporated without boiling. For removing the crystallized salt from the grainers, rakes, imparting a forward movement to the salt, are used. The delivery end is sloped up at an angle of about 30°, and the salt is pushed up on this sloping drain board. The speed of the rake allows the salt to drain before it falls into a belt conveyor. The characteristic feature of grainer operation is that the brine does not boil. With steam pressures of 25 to 40 lbs. in the coils, the brine will be 200 to 210° F. Hotter brine than this makes too fine salt. With lower pressure steam and cooler brine, evaporation is slower and consequently the grain is larger. Due to the presence of calcium sulphate, the coils scale and require to be cleaned periodically. Grainer salt is usually only air dried in storage buildings. When formed by this slower evaporation the salt crystallizes in hopper-shaped crystals. The salt produced by this method is used generally for dairy purposes and as low-grade table salt.

"For the production of the high-grade salt vacuum evaporating pans are used. The form usually employed is of the vertical tube type with a central downtake. Due to the presence of calcium sulphate in the brines heating surfaces gradually become scaled. There is also the phenomenon of "salting up." Most of the salt formed as evaporation proceeds forms as free crystals suspended in the solution. Gradually, however, a coating of salt crystals builds up on all hot surfaces just as scale forms. Consequently vacuum pans have to be boiled out with water or dilute brine at intervals, and at longer intervals calcium sulphate must be drilled out. For removing the salt from the pans a barometric leg is used discharging into an elevator or into centrifugals for eliminating moisture and mother liquor. Vacuum pan salt has a characteristic grain. Since the crystals are suspended in a strongly agitated solution during formation, loose crystal aggregates cannot form and the salt is in the form of hard uniform cubical grains. This structure makes a salt which dissolves more slowly than grainer salt. It is also less hygroscopic, hence makes a free-running table salt. It also occludes less mother liquor. Vacuum pan salt is dried in steam heated driers. It is then screened through various mesh screens, from 20 to 80 mesh."—W. L. HADGER, *Chemical and Metall. Engineering*, February 2, 1921, p. 201. (F.W.)

ETCHING REAGENTS.—Below is a list of common reagents in use at the U.S. Bureau of Standards for etching various metals and alloys before microscopic examination:—

Material.	Method of Etching.	Remarks.
Copper and copper-rich alloys (brass, bronze, aluminium bronze).	An ammoniacal or an acid oxidizing solution.	Suitable oxidizers for use: Hydrogen peroxide, ammonium persulphate, potassium permanganate, chromic acid. Electrolytic in its nature. Nitric acid and chromic acid. The film of precipitated silver must be removed. Accompanying oxidation is necessary to produce satisfactory results. Valuable for certain bronzes.
	Ammoniacal solution of copper ammonium chloride.	
	Oxidizing acids.	
	Aqueous solution of silver nitrate.	
	Concentrated ammonium hydroxide.	
	Heat tinting.	
Aluminium and aluminium-rich alloys.	Hydrofluoric acid.	An approx. 10% aqueous solution is used, a supplementary immersion in concentrated nitric acid or in chromic acid may be necessary to clean the surface. 0.1% aqueous solution is suitable for revealing the constituents, more concentrated for revealing the grain boundaries.
	Aqueous solution of sodium or potassium hydroxide.	
Lead.	Nitric acid.	
Lead and tin alloys, including white metals.	Dilute nitric acid.	Alone or with addition of chromic acid.
	Dilute hydrochloric acid.	
	Aqueous solution of silver nitrate.	
Nickel.	Concentrated nitric acid.	Used alone or in a solution of glacial acetic acid, approx. nitric acid 50%, acetic acid 40%, water 10%.
	Electrolytic etching.	
Nickel-rich alloys (monel metal, benedick nickel, nickel brass).	Same as for nickel. Ferric chloride. Ammonium persulphate.	Same as for nickel.
Zinc and zinc-rich alloys.	Sodium hydroxide; mixture of chromic and nitric acid.	Alcohol solution, approx. 1%
	Iodine. Electrolytic etching.	
Gold, platinum and "noble" metals and alloys.	Aqua regia.	

ETCHING REAGENTS (*continued*)—

Material.	Method of Etching.	Remarks.
Silver and its alloys with copper.	Nitric acid. Ammonium persulphate solutions.	
Wrought iron, "pure" iron.	Nitric acid. Picric acid. Cupric reagent (Stead's reagent).	2% alcohol solution commonly used. 5% alcohol solution. To reveal phosphorous banding and similar structural features.
Carbon steels.	Nitric acid, picric acid and cupric reagent, as above. Hot alkaline sodium picrate. Hydrochloric acid.	Used to colour cementite. 1% alcohol solution.
Alloy steels.	Same reagents as for carbon steels, above. 2% alcoholic picric acid, very prolonged etching. Sodium picrate.	For revealing grain boundaries.
Cast iron.	Picric acid, or nitric acid as above. Heat tinting. Sodium picrate.	For steels showing free carbide. To identify iron phosphide and manganese sulphide.

Chem. and Met. Engineering, February 2, 1921, p. 207. (F.W.)

METALLURGY

THE DEVELOPMENT OF THE ROD MILL.—The Rod mill, although not a new type of mill, has recently been receiving more consideration and application, and is invading the field of the ball mill for stage grinding. Early in the last decade metallurgists became converts to the idea of extreme simplicity in their ore dressing plants, and the ball mill used as a single stage crusher and grinder appealed to this desire. Feed as large as three inches for an 8 ft. diameter mill was recommended for regular practice. Into this scheme the rod mill did not fit as it is a stage grinding machine. This attitude and certain mechanical weaknesses prevented the rod mill from receiving more serious attention.

The rod mill is similar in design to the tube mill, instead of balls or pebbles, it uses rods of approximately the same length as the shell. Line grinding contact instead of point contact results, thereby increasing the effective grinding area per unit of steel. This may be visualized thus, suppose two balls or pebbles are considered. If brought in contact they meet at a point and any ore particle which happens to be at this point is crushed or ground very

fine, depending upon the force of impact. With rods, the action will be similar except that grinding will take place along a line instead of a point. The maximum impact is not as great as with balls, as it is distributed over many points. Fine grinding is not likely to take place if the rod is considered as rigid, the entire grinding action being along a longitudinal line and is concentrated on the two coarsest ore particles which support the rod, allowing the finer particles between a free clearance. In practice, the rods are elastic and not strictly parallel, but maximum grinding action is exerted on the coarsest particles. The rod mill is therefore only suited for stage grinding and particularly for ore dressing ahead of or between concentration stages and where slining is to be avoided. The 'Marathon' mill was the pioneer rod mill. Other designs have since been developed until today there are several standard mills. One of these has a shell 6 feet in diameter and 12 feet long, weighs over fifty tons and contains an eighteen-ton rod load. It is driven by a 150 h.p. motor. The tendency is to have the feed end supported on trunnions and the discharge end on rollers, leaving the greater part of the discharge end open. To prevent splash from such a large

opening and to keep the rods in the mill, a large hinged door, independent of the rotating shell, is used. This allows ready inspection and replacement of the grinding load. The rods used vary from $1\frac{1}{2}$ to 3 inches in diameter. Another type of rod mill supports 81% of the weight of the rotating shell on special self-adjusting rollers and has trunnion feed and discharge ends.

"On a 6 ft. \times 12 ft. rod mill used on a quartzite copper ore in Arizona, the following operating data is given:—

Dry tons feed per 24 hrs.	668.24
Total K.W. hr. per 24 hrs.	2745.6
K.W. hr. per ton feed	4.11
K.W. hr. p. ton—48 material produced	10.65
Horse power	153.3

	+1½in. Mesh.	+½in. Mesh.	+10 Mesh.	+65 Mesh.	+200 Mesh.	200 Mesh.
The Feed Pulp	3.32	44.52	26.12	16.00	3.68	6.36
The Discharge Pulp			6.58	50.26	15.76	27.40

In general, the experience with the rod mill is that it cannot take feed as large as is often given to ball mills or is it proved that it is superior or equal to tube mills where a product finer than 100 linear mesh is desired. The consumption of steel appears to be less than for a ball mill and its original cost is less as the manufacture of rods is better standardized than that of balls."—E. H. ROME, *Engineering and Mining Journal* (N.Y.), May 28, 1921. (F. W.)

OSMIRIDIUM.—The two elements, osmium and iridium, were discovered and isolated by Smithton Tennant in 1801. Since then the various elements of the platinum group have been discovered. These usually are found associated with the mineral osmiridium. They are:—

	Symbol	Atomic Weight	Specific Gravity.	Centigrade Melting Point
Ruthenium	Ru.	101.7	12.26	1800°
Rhodium	Rh.	102.9	12.10	2000°
Palladium	Pd.	106.7	11.50	1500°
Osmium	Os.	190.9	22.48	2500°
Iridium	Ir.	193.1	22.42	2500°
Platinum	Pt.	195.2	21.50	1775°

Osmium is a bluish metal, harder than glass, and the heaviest of all known solids. At a temperature somewhat above the melting point of zinc it undergoes oxidation producing the volatile and highly poisonous tetroxide OsO_4 .

Iridium is a hard, white, lustrous, brittle metal resembling steel. It is malleable at red heat, and melts only in the oxyhydrogen flame. It is a powerful catalytic agent when finely divided.

The mineral osmiridium has a rhombohedral crystallisation. It usually occurs in irregular flattened grains or minute graphitic lamellae. The hardness is 6 to 7, slightly malleable. Lustre is metallic, dull to splendid and glistening. Specific gravity 15.2 to 21.12. The following is the analysis of a Tasmanian sample:—

Platinum	0.37%
Ruthenium	8.19%
Palladium	0.21%
Iridium)	
Rhodium)	33.80%
Osmium (by difference)	57.09%

Gold	0.04%
Iron	0.30%
Copper	Trace

The minerals associated with osmiridium in Tasmania, beside the platinum group, are gold, occasionally diamonds, chromite, magnetite, ilmenite, limonite and heazlewoodite and zaraitite, two nickel minerals peculiar to the country. The rock formation in which it occurs is serpentine, commonly the yellowish-green variety. The deposits of osmiridium were contained originally in certain igneous rocks such as demites and peridotites, which subsequently were converted into serpentines. The mineral is recovered by mining deposits of a pockety nature found in situ, and in placer deposits, and is found in many districts of Tasmania. The methods used in mining and washing the alluvial gravels are often of a primitive nature, and are similar to those employed in gold alluvial mining. The pockety nature of deposits in the rock is an obstacle to large scale operations of underground mining.

In Tasmania large accumulations of osmiridium-bearing gravels exist. Most of the "point metal" used for tipping gold nibs of fountain pens is found in this country. The grains used for this purpose bring the highest price. The greater portion of the mineral used in pre-war times came from Russia, where it is found associated to a minor degree with the platinum. Columbia, South America, also produces osmiridium in association with platinum.

The application of osmiridium to individual uses has extended greatly during recent years. Iridium-platinum ware has an iridium content from 5% to 30%. When the proportion exceeds 30% such an alloy is not attacked by aqua regia. Iridium forms an alloy with 9 parts of platinum, which is extremely hard, elastic as steel, unalterable in the air, and capable of taking a high polish. This alloy has been employed in the production of bars for standard weights and measures. Iridium is also used in the ceramic arts and in photography.

[Osmiridium in Tasmania, Geological Survey Bulletin No. 32, 1921, by A. McINTOSH REID, Asst. Govt. Geologist.] (F.W.)

SUMMARY OF PAPER BY D. H. INGALL, M.Sc., Member (Birmingham), on "THE RELATION BETWEEN MECHANICAL PROPERTIES AND MICROSTRUCTURE IN PURE ROLLED ZINC," presented at the Annual Autumn Meeting of the Institute of Metals, held in Birmingham, on Thursday, September 22, 1921.

The polishing and etching of cast and rolled zinc are investigated in detail. The mechanical properties of pure rolled zinc with a reduction by rolling of 77 to 96% are determined for the following conditions: (1) As rolled; (2) annealed for thirty minutes at 100° C.; (3) annealed for thirty minutes at 150° C.; (4) annealed for thirty minutes at 200° C. It is found that:—

(a) Only average values for mechanical properties are obtainable, as the material is variable.

(b) With the material as rolled and also when annealed at 100° and 150° C., it is ductile "with" and brittle "across" the direction of rolling, with reductions from 77 to about 87%; it is ductile in all directions with 96% reduction by rolling, where the strength has risen from about 6 to about 13 tons per sq. in. These changes are obscured by the microstructure,

which is an equi-axed structure in all cases.

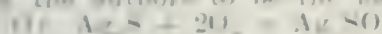
(c) Annealing for thirty minutes at 200° C. renders the material completely brittle and weak, due to a crystallization. (F. W.)

CHLORIDE VOLATILIZATION PROCESS.—The authors of this paper state that chloride volatilization processes have engaged the attention of metallurgists for many years. The paper reviews the subject and the possibilities.

A chloridizing roast is usually accompanied by appreciable losses due to volatilization of the metals as chlorides, often as high as 30%, depending on temperature and character of ore. Croasdale carried out working tests and found great difficulty in recovering the volatilized fume. When, in 1913, Cottrell made public his electrostatic fume precipitation apparatus, impetus was given to the process. O. C. Ralston began investigations which have been continued by the Mining Bureau and University of Utah.

The process is considered adaptable to oxidized, semi-oxidized and carbonate ores of copper, lead and silver, for which the treatment by gravity, concentration or flotation is not suitable. Gold is readily volatilized. Zinc does not volatilize under oxidizing conditions. Excellent results have been obtained on zinc concentrate containing silver and lead, practically all the silver and lead being volatilized, but little zinc. Little work has been done on sulphide ores; experiments, however, are encouraging. When the sulphur content is more than about 5%, a preliminary roast is usually necessary.

In an investigation, the ore is analysed and examined microscopically with regard to physical conditions of the minerals. The porosity of the ore is an important factor, and on this depends the fineness of comminution. Muffle tests are conducted as preliminary, followed by laboratory volatilization tests, in which small scale apparatus is employed. These must be again followed by tests on larger quantities of ore. There is considerable difference of opinion in regard to the reactions which take place. The following are considered by the authors to be the most likely —



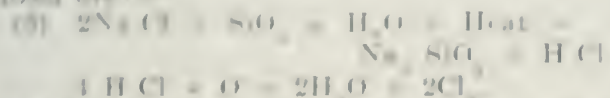
Experiments have shown that silver, lead and other metals can be chloridized and volatilized in the absence of sulphur.



(R) represents the metal volatilized.

Silicates are formed between the sodium oxide and the silica in the ore.

The following reaction represents the chloridizing of most of the metals present in an oxidized ore:



As the charge passes through the furnace the temperature continues to increase, and part of the salt rapidly volatilizes as sodium chloride, while the remainder enters into chloridizing reactions. The result is that the metallic chloride, which does not evaporate rapidly in the zone of lower temperature, is conveyed into the hotter zone, where the chloridizing atmosphere becomes lean. The more

logical method would seem to be to place the charge, consisting of ore and part of the chloridizing reagents in the furnace, to permit the charge to become heated to the proper temperature, and then to supply the remaining portion of the haloid salt to the heated charge in the zone of high temperature.

Ores, such as composed chiefly of limonite and hematite, are inclined to sinter. The chloride salt itself aids this. Most sulphide ores tend to sinter, thereby closing the pores and sealing the minerals from contact with the chloridizing gases. This objectionable feature is usually overcome by the addition of some inert, non-fusible material, such as limestone, from 5 to 15% of this being efficacious.

Baking of the ore, due to moisture, evaporation and temporary fusion of salts which bind the ore together, is to be avoided. A properly designed rabble furnace will prevent this. The temperature necessary for chloridizing and volatilizing the metals from the ore varies with the ore constituent. Copper and lead volatilize at much lower temperature than gold and silver. A temperature of 1,000° C. should completely volatilize all the metals except zinc, the time taken being from 10 to 60 minutes.

Summary of Results of Tests.

Head Assays.

Gold, oz.	Silver, oz.	Lead, %	Zinc, %	Sulphur.
(1) Oxidized zinc concentrate—				
—	6.80	7.10	32.6	—
(2) Oxidized silver-lead ore—				
.07	9.39	15.70	1.25	1.17
(3) Oxidized silver-lead ore—				
.03	3.56	5.35	—	—

Reagents Used.

	Na Cl	Ca Cl ₂	Volatilized Gold.	Silver.	Lead.
(1)	6	6	—	85	80
(2)	10	10	—	80	89
(3)	5	10	70	87	80

T. VARLEY AND C. STEVENSON, *Mining and Scientific Press*. From Serial No. 2247 U.S. Bureau of Mines, July 30, 1921, p. 159. (F.W.)

ELECTRIC FURNACES FOR SILVER, GOLD AND METALS OF LOW MELTING POINT.—For the refining of steel, the melting of copper, nickel, aluminium, brass and bronze, the electric furnace is now in extensive use, and there is ample literature covering this field. The author deals with the application of electric furnaces to the rarer metals, particularly in mints and refineries, and those of low melting point. The electric furnace has the following main advantages over fuel-heated furnaces —

- (1) A more perfect temperature control.
- (2) Less loss by oxidation due to a neutral or reducing atmosphere.
- (3) A higher efficiency.

According to the method of heat generation electric furnaces may be divided into the following main classifications —

(1) Direct arcing furnaces, where the heat is generated in arc between electrodes and the material charged using it as a part of the circuit.

(2) Free burning arc furnaces, where the heat is generated independently of the charge, in arc drawn between the tips of electrodes located above the metal.

(3) Carbon resistor furnaces, having special

heating units located along the sides of the hearth, from which the heat is radiated to the charge, either directly or reverberated.

(4) Induction furnaces, where the heat is generated in the metal itself by induction from primary coils suitably located; the furnace being constructed so that the metal charge forms a secondary closed circuit.

(5) High frequency induction furnaces, where the heat is generated in the metal charge or its container by eddy currents induced by current coils surrounding the crucible.

(6) Wire resistance furnaces.

Silver, with a melting point of about $960^{\circ}\text{C}.$, has no low volatile oxide, and can therefore be exposed to air without loss by oxidation. In the molten state, however, it has the property of absorbing gases, especially oxygen. These are partly retained on cooling and give rise to brittleness, an objectionable feature in rolling for coin. Agitation of the metal is therefore to be avoided. The pouring temperature of fine silver should be from $1,295^{\circ}\text{C}.$ to $1,305^{\circ}\text{C}.$; if either too high or too low the metal is apt to crystallize coarsely on solidifying, making it brittle. For this reason a lip-tilting type of furnace is most suitable.

Among the various types of electric furnaces used now for silver melting are the Rennerfelt, a free burning arc type; the Bailey furnace, a carbon-resistor type; and the Ajax-Northrup furnace, a high frequency induction type. The first-named is largely used in mints; the second is used for smaller operations, melting lots as small as 500 ozs. The crucibles are lifted out and poured separately. Accurate temperature control is possible. The average time for charging, melting and pouring of one heat is given at 67 minutes. It is used largely by sterling silver platers. In the third furnace the crucible is also removable, and small charges can be run.

A wire resistance type of furnace does not produce sufficient heat for melting silver or gold.

Gold should be melted in crucible furnaces only. Not many electric furnaces have been adapted for melting it. The Bailey furnace is suggested. Gold has too high an electrical conductivity to be melted by direct induction. Some small furnaces of the high frequency induction type, where a conductive crucible is used, have been installed. In a six-inch crucible, containing 37lb. gold, the charge is melted in eight minutes.

If gold is alloyed with platinum, a metal having a very high resistivity, conductivity may be decreased sufficiently to melt the alloy by direct induction in a clay or magnesite crucible.

For melting metals of low pouring temperature, such as lead, zinc and tin, an accurate low temperature control furnace is essential. Resistance radiating types are used; also those having wire resistance. A high frequency induction type of furnace, with an iron crucible, is also employed. JONAS HERLENTZ, *Chemical and Metallurgical Engineering*, September 7, 1921: p. 151. (F.W.)

CAST-IRON RESEARCH IN ENGLAND.—A Research Association has been formed in England to investigate the properties of cast-iron, and to disseminate the results of their researches. The Association includes Professor T. Turner,

Dr. W. H. Hatfield, Sir Robert A. Hadfield, Professor C. H. Desch and Professor H. C. H. Carpenter. On the programme of the Association are the following researches: (1) The possibilities of the correct standardisation of the grades of pig iron according to chemical and physical analysis. (2) The classification of pig iron into grades suitable for definite groups of castings of light, medium or heavy form, according to their requirements in service. (3) The influence of mixtures of known grades of pig iron in various melting processes on the final products, of light, medium or heavy design. (4) The practical application of briquetting fine scrap, etc., for cupola and other furnace work. (5) The design and proportions of melting equipment for specific work. Cupola, open hearth or electric furnaces. The effect of melting temperatures, tuyère area, blast pressure and volume, on quality and economic production of castings, and on the wear and tear of furnaces. (6) Methods for elimination of sulphur and other impurities and the problems connected with repeated meltings of scrap, sprues, etc. (7) The correct mixtures, fuel and fluxes for special iron of the semi-steel and malleable types. (8) The fuel problem—chemical and physical properties of coke, coal, calorific values, strength, nature of ash, etc. (9) Moulding sands, facings and washes. Their standardisation, composition and preparation for the various classes of castings. Their sources of supply. (10) Moulding equipments. Machine moulding. Permanent moulds and the use of chills or denseners. (11) The after-treatment of castings. Re-heating and annealing of malleable and other castings. Effects of temperature, time and mass on annealing. (12) Casting temperatures and pouring speeds. The effect of position and size of running and feeding heads. Internal strains and their removal. (13) Cast-iron compositions best suited to resist acid, sea water and gas corrosion. Also problems connected with growth under repeated heating and superheated steam. Hot gases in internal combustion engine cylinders, etc. (14) The properties of cast-irons of various compositions in respect to electrical conductivity, magnetic permeability, etc. (15) Porosity in cast-iron in relation to castings desired to carry hydraulic or heavy gas pressures. (16) Mechanical tests for cast-iron. Their standardisation and best forms for test pieces. (17) To make suggestions relative to the British Engineering Standards Specifications for cast-iron, malleable cast-iron, etc. (18) Machineability. The influence of composition, heat treatment, etc., upon the machineability of cast-iron, semi-steel, malleable cast-iron. The Association encourages firms and individuals to join, who, on payment of a small fee of subscription, will be informed of the results achieved by the Association's research.—CAST IRON RESEARCH IN ENGLAND, *Indian Engineering*, August 13, 1921, p. 91. (J.A.W.)

CHANGES OF ADDRESS.

ASPLAND, C. H., 1/o Rouxville Diamonds, Ltd., Aliwal North; Rose Reef, Ltd., P.O. Kraal, Transvaal.

DEWAR, C. L., 1/o Cons. Langlaagte Mines, Ltd.; Van Ryn Deep, Ltd., P.O. Box 225, Benoni.

MACDONALD, F. G., 1/o Transvaal Silver & Base Metals, Ltd.; Witwatersrand Deep, Ltd., P.O. Box 5, Knights.

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NOVEMBER, 1921.

No. 5.

Proceedings

AT

Ordinary General Meeting, 19th November, 1921.

The Ordinary General Meeting of the Society was held in the Assembly Hall, Scientific and Technical Club, 100, Fox Street, Johannesburg, on Saturday, the 19th November, 1921, at 8 p.m., Mr. F. Wartenweiler (President) in the chair. There were also present:—

21 Members: Messrs. J. Chilton, C. J. Gray, Prof. G. A. Watermeyer, F. W. Watson, A. King, J. R. Thurlow, John Watson, A. Whitby, H. A. White, J. A. Woodburn (Members of Council), J. Q. Braidwood, Dr. W. A. Caldecott, R. A. Cooper, J. M. Dixon, H. L. V. Durell, Jas. Gray, I. D. Hingle, B. Schlesinger, C. B. Simpson, C. D. Tudhope and H. R. S. Wilke.

4 Associates: Messrs. J. A. Boyd, O. A. Gerber, J. Gibson and W. Russell.

2 Visitors and H. A. G. Jeffreys (Secretary).

MINUTES.

The President said they would be unable to confirm the Minutes of the last meeting, the October *Journal* not having yet been published, owing to the fact that they had changed their printers. As most members knew, they had transferred the printing of the *Journal* from Johannesburg to Maritzburg. They would readily understand that the printing of the first *Journal* involved a great deal of dead work, the setting of type for advertisements, the setting of pages, and that printers, as a rule, were not familiar with the printing of technical matter. They expected, however, that the *Journal* would be distributed some time next week. They would therefore defer the confirmation of the minutes of the last meeting.

NEW MEMBERS.

A ballot was taken for the election of new members, and the following were declared unanimously elected:—

BROWN, THOMAS, P.O. Box 1092, Johannesburg; Engineer.

FRAZER, LLOYD S., Standard Oil Co. of New York (S.A.), Johannesburg; Mechanical Engineer.

HENDERSON, JOSEPH, Newcastle Iron and Steel, Ltd., Newcastle, Natal; Metallurgist.

MASKEW, FREDERICK, P.O. Box 3, Brakpan; Mine and Land Surveyor.

REIM, ERNEST P., P.O. Box 2, Benoni; Technical Engineer.

RIGGS, CHARLES H., Newcastle Iron and Steel, Ltd., Newcastle, Natal; Blast Furnace Superintendent.

SMITH, HAROLD H., Minerals Separation, Ltd., P.O. Box 2959, Johannesburg; Mining Engineer.

SOAR, EDWIN, Witbank Colliery, Ltd., P.O. Box 1, Witbank; Colliery Manager.

SYMONS, CHARLES J. D., P.O. Box 469, Johannesburg; Mechanical and Electrical Engineer.

TUDHOPE, CUTHBERT D., City Deep, Ltd., P.O. Box 1111, Johannesburg; Mine Surveyor.

VEITCH, NEIL A., Minerals Separation, Ltd., P.O. Box 2959, Johannesburg; Metallurgist.

The Secretary notified that the following gentlemen had been admitted by the Council as Associates:—

ROWE, CHARLES, P.O. Box 1056, Johannesburg; Metallurgist.

VAUGHAN, WILLIAM E., Jr., 42, Standard Bank Chambers, Johannesburg; Assistant to American Trades Commissioner.

GENERAL BUSINESS.

The Secretary announced that the following Illustrated Lectures would be held during the coming week, under the auspices of the Associated Scientific and Technical Societies:—

"Problems in Local Rocks and Storms," by T. N. Loebe, F.G.S., F.R. Met.S., on 21st November, 1921.

"Commercial Architecture," by H. W. Spicer, on 26th November, 1921.

SOUTH AFRICAN INSTITUTE FOR MEDICAL RESEARCH.

The President directed the attention of members to the announcement on the back page of the Agenda, to the effect that they had been invited by the Director of the South African Institute for Medical Research to pay a visit a fortnight hence to the Institute. He hoped that members would roll up in good numbers.

ELECTION OF OFFICERS, ASSOCIATED SCIENTIFIC AND TECHNICAL SOCIETIES OF SOUTH AFRICA.

The President remarked that, in connection with the election of officers for the Scientific and Technical Club of South Africa, nominations had been called for. It had been announced at the last meeting that any member of any of the constituent societies could make nominations, provided these were sponsored by at least twenty members. In order to give a lead he had taken the matter in hand and had received the support of a number of members for certain nominations. They would also like to have any other nominations. The time was getting short. All nominations should be in by the end of the month.

EXHIBITION AND DEMONSTRATION OF DEVICES, OF PRACTICAL ADVANTAGE.

The President said members would notice on the Agenda a new subject heading: "Exhibition and Demonstration of Devices, etc. of Practical Advantage." It was decided at the last Council Meeting to devote ten to fifteen minutes at every meeting to the exhibition or demonstration of any practical devices, or the showing of charts of interest, the idea being that they would like to encourage the practical man to come forward, and to give him the opportunity of exhibiting any contrivance which was new; it might be a mechanical contrivance, apparatus used in the laboratory, or anything pertaining to underground work. That evening they had a device which, through the courtesy of the Manager of the Ferreira Deep, Mr. Paul Selby, they were able to exhibit, and Mr. F. Brazier, the Reduction Officer, had sent in a short description, which the Secretary would read. Perhaps during the interval members would like to examine the device.

AUTOMATIC CONE CLASSIFIER UNDERFLOW REGULATOR.

Mr. H. Brazier: This device, a full-size model of which is exhibited, was first introduced at the Apex Plant, and with certain alterations has been in use on the Ferreira Deep tube mill dewatering cones since May, 1919. Following the use of "slide plates" and "cut offs" controlled by a native, the automatic action of this regulator was welcomed and used in conjunction with the ordinary diaphragm; it is extremely sensitive, maintaining an even feed to the tube mill. The overflow of the dewatering cone is satisfactory.

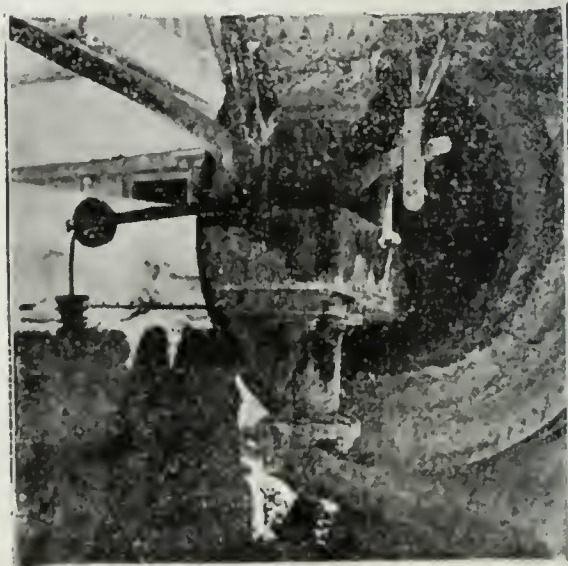
As will be observed, the regulator operates by counter-balance and pulp flow friction. The counter-weight, which is adjustable, serves to keep the valve open and balances it against the normal underflow of the classifier. When this becomes thin, increasing the rate of flow, the increase in friction and pressure on the valve is sufficient to throttle the flow until equilibrium is again established.

The moisture content of the regulated underflow averages 25 per cent. The screen grading is:—

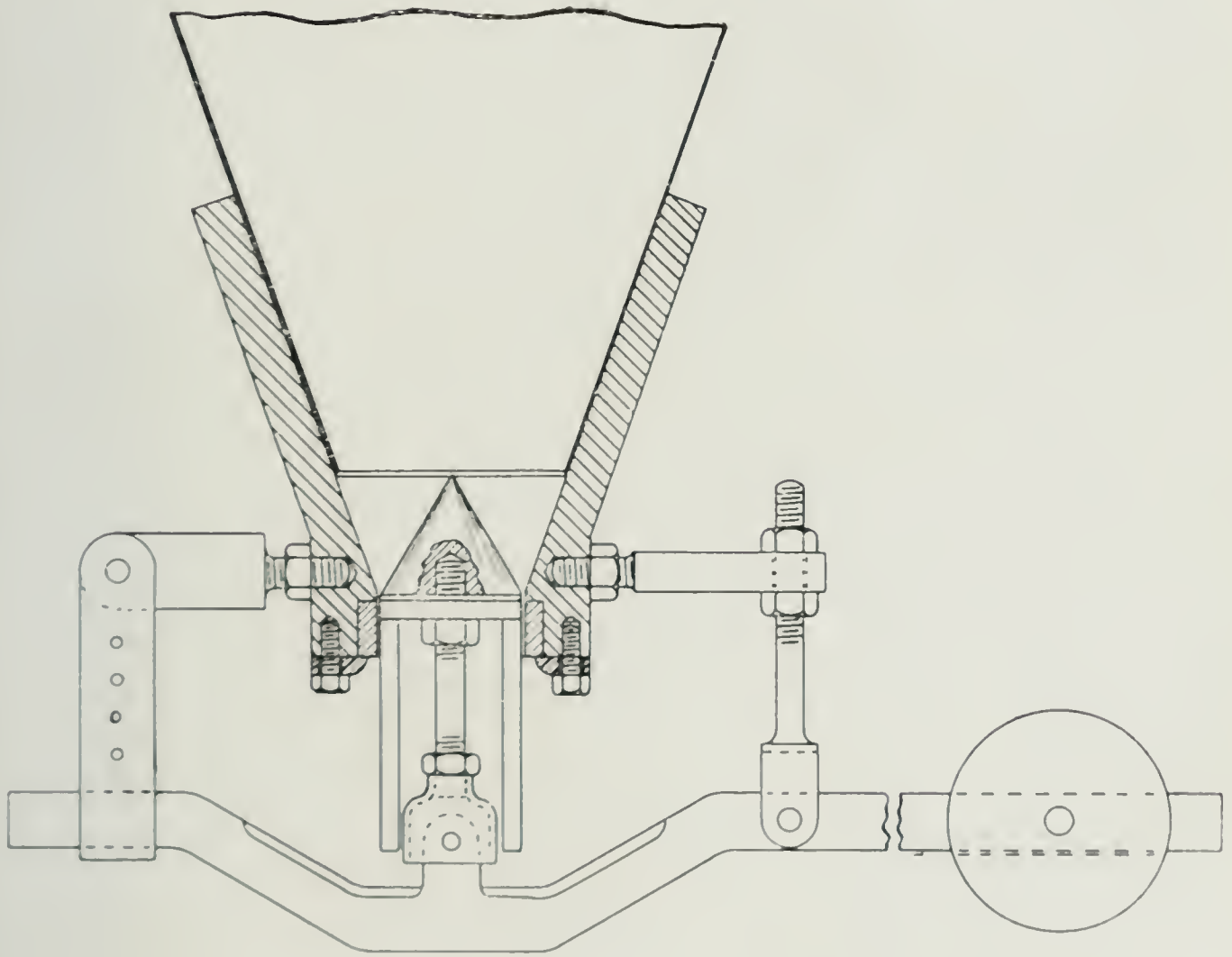
57% + 60 mesh.
33% + 90 mesh.
10% — 90 mesh.

The feed to the tube mill classifier is the underflow pulp of return spitzkasten dealing with the tube mill circuit pulp and original stamp battery pulp from a screen of 200 meshes per square inch.

Maintenance is extremely low.



CLASSIFIER UNDERFLOW REGULATOR.



*AUTOMATIC CONE CLASSIFIER
UNDERFLOW REGULATOR*

NOTES ON AN APPLICATION OF THE CEMENTATION PROCESS TO A BATTERY FOUNDATION.

Mr. B. Schlesinger: When starting up a new stamp battery in the Heidelberg district it was found after 48 hours' work that the foundation, and with it the whole of the superimposed construction, began to rock so dangerously that operations had to be suspended.

An inspection pit was sunk to the underlying shale-foot at A-B (see sketch), and by washing the face of the concrete block so exposed, the writer found that a thin horizontal crack had developed at C-D, completely severing the top three feet from the lower nine feet portion of the block.

The cause of the mishap was badly prepared and badly stamped concrete. Stones, the size of a man's fist, were seen lying loose in large cavities in the body of the foundation.

For further investigation the writer had the mill re-started, with the result that portions of the concrete began dropping out of the block into the inspection pit, in much the same fashion as if the stamps were pounding on tightly packed rubble.

Repairs seemed quite out of the question and it appeared at first sight that the whole of the plant would have to be dismantled and again re-erected upon an entirely new foundation, at a cost prohibitive to the mine owners.

Before dealing this death-blow to his Board the writer decided to attempt saving the foundation by pumping pure cement into it under high pressure. He entrusted the work to the Francois Cementation Syndicate of this town, who lost no time in despatching to the property the necessary plant.

This consisted of a steam pressure-pump with a nine-inch diameter steam cylinder and a two-inch water delivery, a small wooden mixing barrel for cement, which served as an intake for the pump, and an all-important pressure gauge capable of registering pressure up to 10,000 lbs. to the square inch.

The pump was served by a boiler delivering steam at 100 lbs. pressure.

The Process: Nine holes of 7-8th ins. diameter, and 5ft. depth, were drilled into the foundation and distributed as shown in accompanying sketches. The top 9ins. of each hole were enlarged to take a 2-in. pipe 24ins. long, and screwed at one end. Such pipe was cemented into each of the holes

and the cement allowed to bind over night.

The next morning hole No. 1 was connected to the delivery-end of the pump, and clean water forced through before the actual cementing operations was commenced. Thereupon a thin mixture of pure cement and water was pumped into the foundation. At first the liquid entered the concrete block without encountering any resistance whatever, and 17 bags of cement were absorbed before the pressure-gauge on the pump began to show signs of life. The indicator then gradually rose to 100lbs. and 200lbs. per square inch. Simultaneously, with the increasing pressure a tiny stream of water and cement could be observed oozing out of the thin crack previously referred to.

At this stage pumping was discontinued to allow the cement to settle, and hole No. 2 was put into commission and subjected to the same treatment as hole No. 1. After allowing a practically free passage to five bags of cement, the pressure rose rapidly to 800lbs. when pumping was stopped for 12 hours.

Before injecting the remaining seven holes, hole No. 1 was re-treated after freeing it from partially solidified cement by drilling. Two bags of cement sufficed to send the pressure up to 1,000lbs., this being considered the dangerous limit above which the block may have burst.

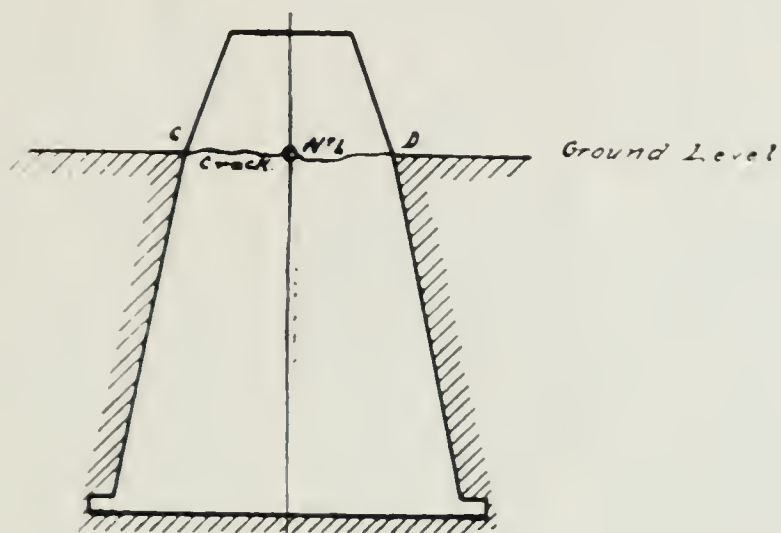
While it required 26 bags of cement and 22 hours of work to complete the first two holes, the remaining seven holes absorbed only fifteen bags of cement and eighteen hours' work.

After completion of the foundation proper the writer decided, as a matter of safety, to solidify the ground surrounding the block. For this purpose six eight-foot holes were drilled about eighteen inches from the foundation, and injected in turn by a mixture of one to one cement and slimes.

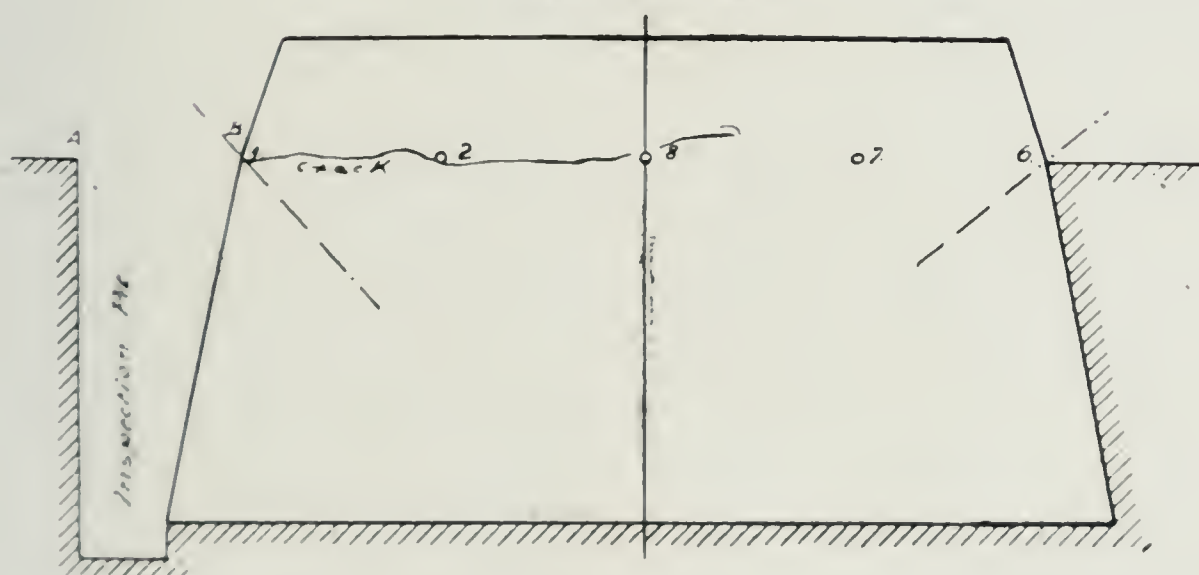
Some interesting phenomena could be noticed. When the pressure on the first outside hole rose to 150lbs. the gauge indicator suddenly dropped to nil, and it was found that the cement solution had broken through to the surface about ten yards from the position of the hole.

One bearing-block of the line shaft, which was only 24 inches in the ground, became injected from one of the outside holes twelve feet away. In proof of this, cement-solution forced its way six inches above the

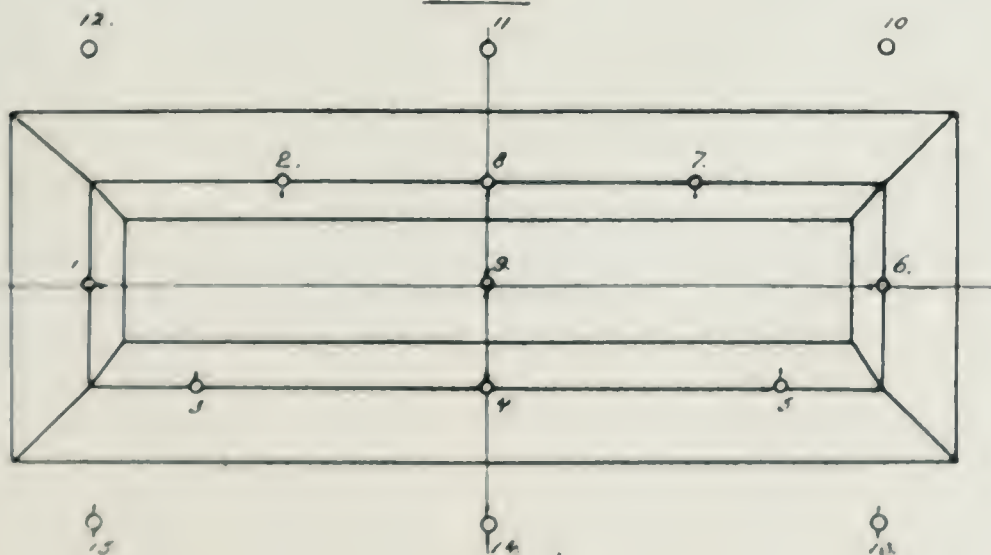
— Side Elevation —



— Front Elevation —



— Plan —



surface through a tiny crack in the block.

It took six days to complete the whole of the process, and 48 bags of cement were used up.

The total costs amounted to roughly £200, inclusive of the charges of the Cementation Syndicate.

After allowing ten days for the injected cement to harden the stamps were again dropped, with entirely satisfactory results.

The plant has now been in full swing for some time, and the foundation is as firm as can be desired.

The President in remarking that the contribution was a most interesting one, said he thought it would be of practical utility elsewhere. To him the mystery was how such a large cavity could exist in a concrete block, and how the block could withstand such tremendous pressure as a thousands pounds to the square inch, or in that neighbourhood. He thought the contribution was rather unique.

OSMIRIDIUM IN THE BANKET REEF.

Mr. R. A. Cooper: The presence of iridium in the banket reef has been known for many years, and at times it has been present in sufficient quantity in the mill black sand concentrates to occasion considerable trouble in gold assaying. Until recently, however, no attempt appears to have been made to obtain the platinum group metals in a saleable form from the black sands.

A small amount of osmiridium concentrate is now being recovered in daily current milling operations on some of our mines.

During the last few months a considerable amount of study has been made on this osmiridium in the Rand Mines Laboratory, and several ounces of the pure metals, iridium, osmium, ruthenium, platinum and rhodium have been prepared.

During these preparations a small portion of a typical crystalline compound of each metal was reserved, and I have much pleasure in exhibiting these compounds and some of the metals. I have not yet found the metal palladium in any raw or treated concentrate.

The President said he considered the exhibit was most fascinating. Perhaps few of them had seen these salts, or the separated, reduced metals. They would observe that the metals were not in the molten form.

They would readily realise that when they considered the high melting point. He thought the collection was a veritable Pandora's Box. It was generally known that these metals were of a much higher market value than gold. He wished to refer them to an abstract on the subject of osmiridium in the October *Journal*.

While they were passing round the exhibits he would like to say they were fortunate that evening that Mr. C. J. Gray had volunteered to explain his system of mineral identification—the system of charts, on which he had worked for a very long time, and which were used in connection with the general identification of minerals.

MINERAL IDENTIFICATION SHEETS AND SIEVES.

Mr. C. J. Gray remarked that his exhibit was not quite a new one. He had explained the method and shown the sheets to the Geological Society* about a year ago, but most of those present that evening had not seen the sheets, and might be interested in them. The idea arose from his experience in the Natal Service. Prospectors used to bring and send in samples of minerals and ask what they were, and it was not always convenient to send them to the Government Analyst in Durban. In many cases one could say straight off what they were, but in other cases a certain amount of work was required. That work had to be fitted in with the ordinary Administrative work, so it had to be done rapidly.

Many books contained mineral identification tables, with a series of determinations of physical or chemical properties leading to identification, but in practice these tables were found unsatisfactory. They took much time to go through, and one was continually striking snags, as for instance failure to determine accurately hardness or crystalline form. Another defect of the tables was that they prescribed a definite order of determination, which had to be followed regardless of the most striking characteristics of the mineral or of the particular determination for which the investigator had facilities. A mineral might have brilliant blue colour and yet that colour might be used only for separating it from others at the end of a long series of determinations, or the investiga-

* A New Method of Using the Physical Characteristics of Minerals for their Identification, by C. J. Gray; Trans. Geol. Society of S.A. Vol. XXIII. 1920.

tor might have facilities for determining specific gravity and find specific gravity given quite a subordinate position in the identification table. What was required was a table in which the determinations could be selected and made in any order at the discretion of the investigator: the exhibit showed how that had been obtained.

There was first a numbered index list of 391 minerals in alphabetical order. Certain closely allied minerals, such as the various amphiboles, were grouped together as one mineral. Then there was a key chart, with the numbers 1 to 391 upon it, and then again a set of 66 perforated sheets, each sheet being perforated in accordance with some particular physical characteristic of minerals, so that when it was placed in register on the key chart only those numbers representing minerals which might have that particular characteristic showed through the perforations. For instance, if the perforated sheet for red colour were placed over the key chart the numbers remaining exposed represented only those minerals which are sometimes red.

The way in which the sheets were used would be shown by using the same mineral as that used before the Geological Society. It was a mineral which happened to have been first identified in Natal, and perhaps in South Africa, by Mr. J. S. Hedges, by use of the sheets. The mineral had sub-metallic lustre, was black, gave a black streak, its hardness was slightly above six on Mohr's scale, and its specific gravity was 5.8.

The key sheet was then laid down and upon it, in register, perforated sheets:—I. 1, Lustre—Metallic or Submetallic; II. 1, Colour—Black, nearly black, or dark grey; III. 1, Streak—Black or dark-grey; V. 10, Hardness—6 to 7; VII. 12, Specific gravity—5.4 to 6.1. The only key number remaining exposed was 94, which, on reference to the index list, was found to be Columbite-Tantalite. It was pointed out that the same

result could be obtained by using an approximate determination of hardness and sheet V. 3. Hardness: Not scratched by penknife; instead of the more limited sheet V. 10, and that it was immaterial in which order the sheets were used.

While on the particular case of Columbite a few determinations brought the number of possible minerals down to one, that would, especially with non-metallic minerals, not always happen. In practice the user of the sheets would, without carrying out more than rough tests, bring the number down to, say, half a dozen, ascertain from the index list what those were, reject two or three because of his knowledge of minerals, and apply chemical or blowpipe tests, or make more accurate determination of hardness of specific gravity to settle the question between those remaining. It was pointed out that it was an advantage of the method that the investigator was reminded of the minerals which were similar to the sample, and that he could not, as without the sheets, make a wrong identification through forgetting a possible mineral.

Mr. H. A. White supposed that if they brought the number down to nothing by use of the sheets it would prove that the mineral was not on the list.

Mr. C. J. Gray replied in the affirmative, but said that there was also the possibility that a mistake had been made, and that it would be well to go over the determination again.

The President thanked Mr. Gray, on behalf of members, for having volunteered to demonstrate his method.

The President thought he ought to preface the reading of the next paper with an explanation regarding its premature appearance in the form of extracts in one of the local papers. It came about through a misunderstanding, and the editor had apologised.

SOME NOTES ON THE PILGRIM'S REST GOLDFIELDS

By H. C. F. BELL.

A great deal has been written lately about the decline of the Rand, and the question of finding new gold fields. It, therefore, seems opportune to give some notes on one of the oldest goldfields in South Africa, namely the Pilgrim's Rest district.

The Pilgrim's Rest official Mining District

is approximately 110 miles wide by 140 miles long. It includes 93 proclaimed farms, 127 farms available for prospecting and 9 concession farms. In the year 1920 the district produced 106,823 ounces of fine gold which, if valued at 105/- per ounce, would be worth £560,820. This represents

an average production of £46,735 worth of gold per month, of which approximately one-third was produced by small mines and diggers.

The two largest mining companies at present working are the Transvaal Gold Mining Estates, Ltd., often spoken of as the T.G.M.E., and the Glynn's Lydenburg Limited. There seems to be a prevalent idea that the T.G.M.E. hold most of the district, and all the plums. This is not so, though some of its properties are the best in the district. There is room for, and there will certainly be, many more good mines, while there is still life in the present ones.

An old official of the T.G.M.E. recently told the writer of an incident which happened 25 years ago. He had not been out very long from the Old Country when he decided to get his wife out, and when he told the general manager of his intention, the reply came: "Don't be a fool; the mine will be worked out in twelve months' time." The mine is, however, still going strong. Similar incidents are still happening in the district, and will probably go on happening for another fifty years. Until the world's trade is adjusted to a stable and balanced state the price of gold is likely to remain at a premium. Gold mining will, therefore, be a profitable industry for a long time to come, more especially as the present world output is far below the pre-war output.

Many of the mining men are being turned out of the Rand mines by the Phthisis Board, and many others are leaving before they lose their good health. Some of these have saved money, and wish to acquire small mines either on tribute or as their own concerns. They should, in the first place, obtain Memoir No. 5 of the Government Geological Survey, by A. L. Hall, which is most interesting and instructive, and is obtainable at the Government Printing Office, Pretoria. Apart from the possibilities open to smaller men, sufficient mineralised areas are available, which warrant the most thorough and systematic prospecting by strong exploration companies.

The Pilgrims Rest District contains 19 different reefs, which have been, or are being, worked, and also very many "Leaders." Before proceeding to give a few notes on each reef it is advisable to briefly describe the class of mining peculiar to the district.

The reefs are unlike the "Banket" of the Rand. They are true quartz reefs, and

lie conformably with the strata, dipping at about four degrees West. In thickness they average approximately twelve inches, but various thicknesses are obtained from two inches to ten feet. Their texture is disintegrated, the predominant constituent being quartz. Their colour is usually reddish brown, owing to the presence of oxides of iron, which is the residue from the decomposition of iron pyrite which, at one time, existed in the reef. The presence of "Reef Gold" (as distinct from "Leader Gold") is directly associated with the presence of decomposed or undecomposed iron pyrite.

The reef is usually friable and easy to pick. When blasting is necessary the holes are set so that the concussion of the charge will loosen the reef and not blast out a bench, as is the case on the Rand. The only exception to this is on the sandstone reef mines, near Sabie, where the reef is unoxidised. Most of the ore is got from the stope faces by picking, 4lb. picks being used. Each pick boy has two pick-heads and one handle, and while he uses one pick the other is taken away by a "piccanin." Each stope has what is called a "jumper piccanin," who is a small boy, whose rate of pay is usually from 7/6 to 17/6 per month, and his work is to keep the stoping boys supplied with sharp drills and picks. Reef and waste are picked alternately. After the reef is picked down and shovelled away, the footwall is usually brushed up by each pick boy, so that the "fines" of the reef will not be lost with the waste. The waste is then picked down and packed behind the stoping boys. Each stope has a "timber boy," who puts in props to support the hanging. Each prop has a good head board.

When the reef lies in soft decomposed ground a stope width sufficiently big for a boy to sit up in is carried, but when the country rock is hard, then the stopes are kept as narrow as possible so as to avoid blasting. Many stopes are to be found which have stoping widths varying from 12 to 18 inches, and this on a reef dipping at only four degrees. Such a thing on the Rand is unthinkable. In these narrow stopes picking is substituted by chiselling. The reef is chiselled out until near the end of the shift, when each boy drills several short holes. These are blasted at the end of the shift to loosen the reef for the following day.

The Glynn's Reef at Sabie is particularly suited for clean mining. The reef can be picked out and sent to the mill with the inclusion of only two or three inches of waste. The country is usually fairly hard. In some places there lies over the reef a slate from six to twelve inches thick, which can be barred down and used for waste packing, with the double advantage of saving timber and of giving a comfortable stope-width. Under such conditions a 12-inch reef, valued at only 10 dwts., can be made to pay. In some mines where the ground is fairly soft a 5-inch reef, valued at 14 dwts., can be made to pay. This fact must not be lost sight of by people who are interested, or have the opportunity of being interested in local mines or enterprises.

The Reefs of the District.

Mount Anderson, which, by the way, is the highest point in the Transvaal, has been a constant gold producer for many years. Most of the work there has been done on Leaders by individual workers, and there are still very good chances of finding more payable leaders. A small company, called "The Mountain Mines," has worked there for some time on a flat reef, which has not been definitely correlated with any other, but is probably the "Finsbury," or Upper Reef mentioned in Memoir No. 5 by A. L. Hall. Lower down there are the Button and Davidson Reefs, on the farms "Nooitgedacht" and "Finsbury." These reefs are in the Pretoria series, and are thin and of low grade. The Button Reef, which was worked by a thirty-stamp mill many years ago, thickened to three or four feet in some places. The other reef is thinner and poorer. The experience gained in the last few years on the Language and Columbia Hill Shale Reefs shows that all shale reefs require a great deal of development. The reefs are either very good or very poor: a drive on thin, poor reef will sometimes most unexpectedly go into a rich shoot.

The Language Reef—This reef lies a little over 1,000 feet above the base of the Pretoria series. It has been worked with success by the New Frankfort Syndicate, on whose property this reef, though very thin, has the redeeming feature of containing very rich chutes, locally known as "channels." These channels form very suddenly and are usually bounded by well-defined walls. "Channel" ore is quite different from the ordinary reef, its chief feature being the inclusion of irregular shaped

pieces of shale, which lie at various angles. The channels usually form from the reef plane down into the footwall. A soft grey "pug" (soft shale) is often associated with channel ore, and this "pug," when met with while driving on reef, is often a sign that a channel is near by.

Below the Language Reef, on the New Frankfort ground, there are several quartz leaders cutting across the formation and carrying excellent values in places. In some parts they are very pyritic, but continue to carry good values. This pyritic ore has not been found difficult to treat with cyanide.

About 250 feet below the Language Reef another aparallel reef exists, about which very little is known. A fair amount of prospecting has been done on this reef, on and near the property of the New Frankfort Syndicate, proving its consistency and continuity to be more favourable than that of the Language Reef, but the values, so far obtained, are very low.

The contacts between the leaders and these bedded reefs have not yet been found. It is possible that there may be some enrichment at the contacts.

The New Frankfort Syndicate is at present doing all its work in thick forest, and the tracing of outcrops necessitates chopping travelling ways with axes and bush knives.

The Language Reef has been traced for some distance on the farm "Morgenzon," but here the values have been low, though not altogether discouraging.

This reef certainly deserves more attention, and there is every possibility of other payable portions of it being found.

The Columbia Hill Shale Reef.—The next Reef in the Pretoria series is the Columbia Hill Shale Reef. The only place where this has been found is above the Peach Tree Mine, of the T.G.M.E. Here it has much the same characteristics as the Language Reef, on the New Frankfort Syndicate, and it may be a purely local patch of reef, and if so, it teaches us an important lesson, namely, not to confine our prospecting to certain horizons. However, as it is proving to be such an excellent thing attempts are being made to find it elsewhere.

Where this reef was first worked it is about 550 feet above the Theta Reef, but further to the South West it is only 450 feet above

The Shale Reef.—From 20 to 30 feet above the base of the Pretoria series there exists a thin reef, which used to be spoken of as "The Shale Reef." In recent years, however, it has been overshadowed by the Columbia Hill Shale Reef and the Language Reef.

A rich patch of this reef is said to have been mined at Messrs. Burnham and Munro's Mine at Graskop (J. E. Andersen, *Mines and Claim Holders' Journal*, August, 1897).

The other reef now being opened up at Frankfort, appears to be the Shale Reef, lying very close to the Bevit's Reef.

The Bevit's Reef.—This reef lies at the base of the Pretoria series. It can be found nearly everywhere, but is usually only from $\frac{1}{2}$ -in. to 3in. thick. Like most of the other reefs, it has an exception to the rule, and at Frankfort, on the property of the New Lisbon Berlyn Co., it carried excellent values and was worked for a long time.

The reef is always easy to find, as it lies immediately on top of a standstone, which is from 1ft. to 3ft. thick. Under the sandstone is a breccia, locally called the "Bevits Conglomerate," and under this is the "Giant Chert," then the dolomite series begins.

The Theta Reefs.—In many places within a few miles of the village of Pilgrims Rest there are two Theta Reefs, called the Top Theta and the Bottom Theta. The Top Theta lies within three or four feet of, and just under the Giant Chert. The Bottom Theta lies from 30ft. to 70ft. lower. The lower reef is the more consistent.

The horizon of these two reefs, taking the Giant Chert as a guide, can be traced over a large area. Going South from Sabie the formation on this horizon is very much decomposed, with the consequence that prospecting is difficult and expensive. The strata are so covered with surface soil that the only sure way to ascertain the presence or absence of a reef is either to put in drives and then rise and sink, or to sink a surface winze on a suitable slope. Going north, there is not quite so much decomposition, and therefore prospecting is easier, but when the strata get hard and stand out clearly on the hills the chances of finding payable reefs are not so promising as in softer formations. Payable reefs usually lie in, or near, decomposed ground. There are, however, many places where good reef lies in hard dolomite or quartzite, but in these

cases the reef itself is usually oxidised and therefore soft.

On the farm Waterfall North, near Sabie, a small mill is working on what is thought to be a slipped portion of the Theta Reef. If this is so, then a good deal more prospecting is certainly necessary above this mine, on the proper Theta horizon.

Further north the Theta Reef has been worked on the farm Desire for a long time, but from here, going east over hills which terminate in a high point overlooking Graskop railway station, is an area which warrants a great deal of development. I say development, because the reef has already been found in many places, and the matter of finding it in other places is quite easy. It has already been, and is being, mined near the main road leading from Pilgrims Rest to Graskop. The undeveloped area commences about half a mile south of the road. Most of it has been pegged, and it is to be hoped that some active work will be commenced on it in the near future.

From "Black Hills," north of Pilgrims Rest, comparatively little systematic prospecting has been done up to Frankfort, where the Theta Reef was worked by the New Lisbon Berlyn Co. Here it was worked for many years, until most of the oxidised portions of the reef were taken out and the pyritic ore left.

The Beta Reef.—This reef lies from 45 to 70 feet below the bottom Theta Reef, and has been mined only on the Central mines of the T.G.M.E.

The Slate Reef.—This reef lies about 10ft. above the "Slate Marker," the latter being a persistent band of slate outcropping clearly for many miles, and used as a marker in locating the "Portuguese Reef." The Slate Reef was mined at Black Hills, and near the T.G.M.E. magazine there is a small payable patch. Although this reef has not yet been found in large payable quantities, it must not be taken for granted that payable patches will not be found in other parts of the district.

The Portuguese Reef.—The "Slate Marker" mentioned above lies about 100ft. below the middle Chert, which, in turn, is from 300ft. to 350ft. below the Giant Chert. A few feet under the Slate Marker is a series of alternating layers of dolomite and chert, locally known as the Bread and Butter Dolomite. This is always easy to find, and is an excellent guide.

The Portuguese Reef lies from 80ft. to 110ft. below the Slate Marker. The whole

of the "Chi" Mine of the T.G.M.E. was on this reef, but until recent years it was thought to be on the Beta Reef. The T.G.M.E. are now developing the northern extension of this mine, and there is already a substantial tonnage of payable ore in sight. The Ponieskrantz North and Grootfontein Mines are also on this reef.

On the farm Olifantsgeraamte several thousand tons of fairly good reef were developed, but the reef has not yet been definitely correlated. In my opinion it is the Portuguese Reef.

The Glynn's Reef.—Of all the reefs in the district the Glynn's Reef is to-day the largest producer, and it promises to greatly increase its output. It is now being worked at Elandsdrift, Sabie and Vaalhoek. The distance between the first and third of these places, as the crow flies, is $32\frac{1}{2}$ miles. Between these points attempts have been made to locate other patches of payable Glynn's Reef, but, like the other reefs in the district, it does not form everywhere. It was mined some years ago at MacMac. From the "Bonnet," a small kopje on the road to Graskop from Pilgrims Rest, is a stretch of country terminating at Sabie, which requires a great deal of sound prospecting. The formation on the Glynn's Reef horizon along this area has that smooth, soft appearance which is considered good for the presence of payable reef.

The area immediately south of Sabie promises to be a lively mining quarter soon. Next to the Glynn's Lydenburg is the Glynn's Pretoria G.M. Co., and near the latter is the Heather Syndicate, a flourishing little five-stamp proposition. In the same area several syndicates have started sinking for the reef.

North of Pilgrims Rest, from where the Waterfall River joins the Blyde River, to Vaalhoek, is another stretch of country which is likely to contain payable Glynn's Reef. At Vaalhoek this reef is being developed and mined, and is giving good results.

The guide used in looking for the Glynn's Reef is the "Blyde River Quartzite." Going north from the farm Graskop this band of quartzite is easy to find, the average thickness being about five feet, but going south to, and beyond Sabie, it is not so easy to find, due partly to its being thinner and partly to the fact that its texture does not appear to be so compact as it is further north. There is, however, another indicator which assists in locating the Glynn's

Reef, and that is a band of hard, bluish slate, which lies from five to ten feet above the Blyde River Quartzite. Above these two indicators there is a strip of dolomite roughly one hundred feet thick, which I call the "Black Dolomites." This strip of dolomite has a darker general appearance than the rest of the dolomite, and weathers in such a way that lumps of dolomite with grass growing between them, form a gentle slope on the hill side instead of the usual krantzes. Moreover, aloes grow among these lumps more freely than in any other part of the dolomite series. These "Black Dolomites" can be traced from Spitzkop to Vaalhoek.

The distance from the Blyde River Quartzite down to the Glynn's Reef varies from 60ft. at Sabie to 160ft. at Vaalhoek.

The Sandstone Reef. This reef is partly dealt with in the paragraph on the Black Reef series. I am not well acquainted with any particular method of locating it throughout the series, but near Sabie it is said to lie about 200ft. below the Glynn's Reef. Immediately above the reef there is about 14ft. of hard quartzite, which has a slightly bluish colour.

This reef seems to have undergone less decomposition than the other reefs, and at Sabie it is being worked for the production of iron pyrite.

The Thelma Reef.—This is neither a vertical nor a bedded reef. It has been mined for several years by the T.G.M.E. at their Vaalhoek Mine. It forms only on the west side of the Vaalhoek Dyke in lenticular bodies in the dolomite, roughly parallel to the dyke. Most of these bodies are joined by horizontal bodies of similar reef, and in contact with the west wall of the dyke, the reef formed for a long distance carrying very high values.

The outcrop of this dyke can be traced for many miles, and where it crosses some of the upper reef horizons the Thelma Reef is found.

Thelma Reef has not been found very extensively under the bedded reefs, and this fact, coupled with its peculiar nature, leads one to believe that it is formed partly by the redeposition of the bedded reef immediately above it.

Vertical Reefs and Leaders.—There are numerous and uncertain in value. To go into details would require a separate paper. In the area round Mt. Anderson, and from the Waterfall River to Maripe Mountain, vertical quartz leaders abound. Some carry

little or no gold, while others are exceptionally rich. One leader recently opened up gave 294 ozs. from 20 tons of ore crushed. Of vertical reefs there are three being worked, namely "The Rietfontein Reef," "The Sunlight Reef," and the reef being worked by the "Hefta Syndicate." On the farm Sabie Nook there are several vertical reefs, one of which is the Rietfontein Reef, and which carries some encouraging values. Vertical reefs several miles further north have been located, but insufficient work has been done on them to indicate their merits. They are probably the same series as on Sabie Nook.

In recent months considerable activity is being shown in the opening up and working of leaders with profitable results to the "small man."

The Black Reef Series.—One of the most interesting belts of country in the district is the long strip of Black Reef Series running along the edge of "The Berg," almost due north and south, and extending from south-east of Sabie to Marieps Mountain. From it a great amount of alluvial and "leader" gold has been won. Alluvial diggings in this belt start from the eastern portion of the farm Spitzkop No. 39, but in the neighbourhood of Spitzkop Mountain there are other alluvial workings which lie in the lower part of the dolomite series.

About two miles north of Sabie there is a busy little group of mines producing iron pyrite from the sandstone reef. This class of mining, which has been in vogue for the last few years only, is very attractive, owing to its simplicity and cleanliness. The Sandstone reef is very pyritic and hard. The ore is crushed to a coarse mesh and passed over concentrating tables. The concentrates, which vary in gold contents from 2 ozs. to 3 ozs., and in sulphur from 40 to 45 per cent., are railed to chemical and explosive works, chiefly for the manufacture of sulphuric acid.

Further north there are the Mac-Mac and the Graskop diggings. Running through the Graskop diggings is the Mali-Dyke, and here is the "Mali-Dyke" gold mine. This mine is most interesting in that the reef is in immediate contact with the wall of the dyke, which is vertical. The reef splits in places and runs right into the dyke, and even in the dyke it carries payable gold. This dyke is not easy to trace, but what appears to be the Mali-Dyke outcrops at Waterfall, and there is reef in the same vicinity. Some serious prospecting here might open up a

payable mine. When the dyke has once been unmistakably located in a second place the problem of tracing it further afield will be much easier. Its probable line traverses the farms Lisbon, Berlyn, London, Ledouphine and Goedgelooft. It is possible that the main dyke which runs through the New Chum Mine is the Mali-Dyke.

Several miles further north the Sandstone reef has been found in several places carrying fairly good values, but very little work has been done towards proving the extent and value of this reef. One area in particular, where several good assays have been obtained, requires development, and may prove to be a profitable proposition. Water is a little troublesome, but could be overcome with hand-pumps.

The next important area is the one locally known as "Waterfall," situated on the farms Lisbon and Berlyn, where there have been extensive alluvial diggings and a fair amount of reef mining. The New Lisbon Berlyn Company did a lot of work here many years ago. A small mill is now in the course of erection, and alluvial digging is still being carried on in a quiet way. There are two reefs here, called the "Robertson" and the "Pidgeon" reef. They are above the Sandstone reef and below the Glynn's Lydenburg reef.

Between this area and Belvedere is an area in which some very rich leaders have been found, one of the most noted of which was the "Tucker Leader," which, though very narrow, extended for 1,400ft. into the hill and produced many thousands of pounds' worth of gold.

Not very far from here is the "New Chum Syndicate" Mine. This has been working for several years. A main drive, 2,000ft., has been driven into a hill parallel to a large dyke. This drive intersected several small cross dykes and leaders, and of the latter the biggest, which is called "Big Ben," runs right through the dyke. The smaller leaders do not run through, but there are rich leaders on both sides of the dyke. For a long time prospectors have maintained that the leaders on the east side of the dykes do not carry gold, but this belief has been definitely disproved at the New Chum Mine.

At the Hefta Syndicate Mine, in this same area, nearly all the gold is in the form of nuggets, and some very fine specimens have been obtained. Most of the gold is found in a seam of dark-coloured clay, in

contact with a vertical reef. Until recently it was believed that there was only one gold-bearing horizon, but recent development has proved that there is payable gold at other horizons.

In this vicinity a gold-bearing flat reef has also been found, but no work has been done on it. It is alleged that further north there are clay seams of possibly good value which have not been developed, and no serious prospecting has been done to find others.

Just below the junction of the Truer with the Blyde River, amidst beautiful scenery, are situated the "Bourke's Luck" and the "Deintje" Gold Mines. These two mines are, I believe, on the same reef, called by some the "Bourke's Luck" reef, and by others the "Sherwell" reef. I think the former theory is correct, and that the Sherwell reef is lower down.

The Deintje mine is dealing with a pyritic ore containing a high percentage of copper, and the concentrates are being sent overseas for treatment. The Bourke's Luck mine has a large dyke running through it, and associated with this dyke are numerous leaders, which in places almost form a stock-work. These leaders have supplied practically all the ore for the mill. Some time ago the mine closed down, but has recently been re-started.

Several miles further north is a baby mine, where a little three-stamp mill is situated amongst the wild surroundings of Mariëp's Kop. Only vertical quartz leaders are being worked at present.

Comparatively little prospecting has been done in this area, but those who know it fairly well believe that it offers excellent opportunities for the "small man."

Alluvial Deposits. Apart from the alluvial deposits mentioned under the heading "Black Reef Series," there is still some gold in the famous Pilgrim's Creek, but the best of it has been taken out, and that which remains lies under thick overburden. It will probably be worked on a large scale at some distant future date by the owners, the T.G.M.E.

There must be a great deal of rich alluvial wash in the leader area, stretching from the farm Lisbon to Mariëp's Kop, but unfortunately a great deal of it has been covered with very thick surface soil. A considerable amount of alluvial gold has been won on the north and south sides of Spitzkop Mountain, also at Hendrikdal and Ross Hill. These places are not totally worked out, but the remaining ground is difficult

to handle. Large quantities of alluvial gold have been won from the farms Nootgedacht, Finsbury and Natalshoop. Though there is little alluvial digging going on now the news of "rich strikes" is periodically heard.

Pyritic Ores.—The production of iron pyrites has become an established industry in the district. The main producers are the mines on the Sandstone reef at Sabie; next to these are the Rietfontein and the Deintje gold mines.

The New Lisbon Berlyn Company's Mine at Frankfort contains an enormous quantity of sulphide ore, but unfortunately this ore and that at Deintje are too refractory for the ordinary treatment of iron pyrite now in vogue at the various explosive and chemical works. There are several other places in the district where sulphide ores exist, notably at the North Clewer Mine of the Pilgrim's Rest Consolidated Goldfields, Ltd.

Unfortunately all the local pyritic ores cannot be disposed of as many of the companies producing explosives and sulphuric acid are importing most of their requirements from Spain. The demand for local concentrates is decreasing. Only a few weeks ago one explosives company closed down a part of the roasting plant which was used to treat the local pyrites, and converted it to treat Spanish ore.

It is hoped that the Government will investigate this question thoroughly and help to build up our local industry, as it would be a calamity if local mining propositions which have been equipped and started working have to be closed down because they cannot compete with the Spanish ore. The loss to this country is greater than at first appears, for most of the local pyritic ores contain high gold values, whereas the imported ore contains no gold at all.

In conclusion, I wish to express my hope that these brief notes will be followed by liberal discussion and constructive criticism from the many mining men and prospectors who have detailed and valuable knowledge of various parts of the district.

Prof. G. A. Watermeyer, in asking those present to pass a vote of thanks to the author for his exceedingly interesting description of the district, said he was afraid he could not criticize the paper as he had but a limited acquaintance with Pilgrim's Rest. He had visited it on one occasion, but his knowledge extended more to the Barberton district. He noticed the

author lamented the want of better prospectors. His, the speaker's, experience of the prospector was that while he was without money and had to live on a bag of mealie meal a month he often displayed more intelligence than the man with money, but when, after discovering and disposing of a property he found himself comparatively affluent, his intelligence fell short of enabling him to keep what he had gained. His money was soon spent, and he had to begin again.

The unfortunate part about the deposits in the district to which he was referring was the want of continuity in value. A case in point that he remembered was that of development done for about 300ft. horizontal on the reef, which gave remarkably good values; it was thought good enough to sink on it, they sank something in the neighbourhood of 200ft., and the good values held through all that distance. Immediately they started stoping and getting a little more than three feet from their drives and winzes the values gave out. The property was bought on that development, and although a great deal of stoping was done off these drives and winzes they did not get their money back. He had pleasure in proposing a very hearty vote of thanks to Mr. Bell for his very interesting paper.

Mr. J. A. Woodburn had great pleasure in supporting the vote of thanks which had just been proposed.

He had spent three years in the Pilgrims Rest district about 25 years ago, and last July he rode over the greater portion of it during a fortnight's holiday there. One point which had struck him when he arrived in the district 25 years ago, and which had been confirmed recently, was this, that while about 19 or 20 reefs had been mentioned that evening as occurring in the district, he did not know of a single instance, nor had any ever been brought to his notice where either in the shales above the dolomite were two reefs worked immediately above each other on the same property, nor in the upper dolomite above the Blyde River quartzite (or middle sandstone) were two reefs worked on the same hill or in the same mine, one immediately above the other; nor in the lower dolomite below the middle sandstones were two reefs worked one above the other in the same property. One was inclined to think that, therefore, if there were so many reefs there was only one that seemed to be workable in each of those particular areas. He had had an experience

of a reef in the shales, not exactly in the Pilgrims Rest district, but in the Pretoria Shales, corresponding to the Button or Finsbury reef where, apparently two outcrops, one 50 feet above the other, proved, on development, to be one and the same reef. The two outcrops were distinctly seen two to three feet, and up to six feet, in thickness, the lower outcrop being traceable for a considerable distance, the other outcrop being found on the slope of the hill fully 50 feet higher up. The natural dip of the formation was to the west. A drive was started in an easterly direction from the upper outcrop and another drive in a northerly direction from the lower outcrop. When about 400ft. in, the drive from the lower outcrop suddenly rose up about 13ft., then went for another 100ft., and then rose up 30ft. or 40ft., the reef continuing in the drive, and finally connected with the eastern drive from the upper outcrop. Now the impression he had was that a similar thing probably occurred in the Pilgrims Rest district, both in the shales and in the dolomites. They were not true bedded reefs in the sense of having been laid down at the same time as the dolomites, consequently it was a natural conclusion that they might occur in various zones, although they were apparently interbedded over considerable areas.

With regard to the Vaalhoek mine which, together with Elandsdrift mine, were the only two important discoveries which had been opened up geologically during the last 25 years, the others were merely continuations of what had been found before. Vaalhoek reef was said to be 100ft. or 120ft. below the Blyde River quartzite. There was no doubt about this, because this quartzite was 20ft. to 30ft. thick, and exposed on the slope of the hill above the mine. Quite recently, when at Sabie, while discussing the matter, a thin band, 9in. to 18in. thick, was shown him of Blyde River quartzite occurring about 60ft. to 80ft. above Glynn's Lydenburg Reef. He expressed great doubt on the matter, because as far as his memory went there were 20ft. to 30ft. of quartzite in the dolomite up on the hill between Sabie and Spitskop, and it was his impression that this small band of quartzite had been wrongly taken as Blyde River quartzite. The exact horizon between Glynn's Lydenburg and Vaalhoek Reefs was not comparable, because Glynn's Lydenburg Reef was only about 100ft. above the base of the dolomites,

while the Vaalhoek Reef had several hundred feet of dolomite below it.

He did not want, however, to convey the impression because only one workable reef was found in each of these formations that prospecting should not be carried on along those horizons, but he did think a little more correlation and a little more information geologically, particularly with regard to dykes, faults and flowsheets, would greatly assist the further development of that most interesting district. It was one of the most interesting mining districts outside that of the Rand, and he certainly was of the opinion that quite a number of valuable properties, not very large probably, but certainly valuable from a payability point of view, would yet be opened up in the Pilgrims Rest district.

Reference has been made to Elandsdrift. There, there was an occurrence which rather supported the opinion he had expressed that the same reef might take different positions in the dolomite formation. There they had three reefs within 24 feet of each other. Only one of the three was worked as being sufficiently valuable to the mine, and was interbedded in the dolomite over a considerable area, but at one portion of the property it looked to him as if the three reefs had been joined together by a huge body of quartz. This body was found practically at the surface and was several hundred feet long and fully a hundred broad, and was locally called "The Blow," the interbedded reefs running into it. This body gave very high values and many rich specimens showing visible gold were found in it. Similar occurrences on a minor scale could be noted at various other parts of the district. The suggestion of an upper and lower Theta reef rather bore this out, and it seemed to him that considerably more carefully detailed correlation would lead to a great deal more information. For instance, he had noticed between Sabie and Elandsdrift what looked like the continuation of the Mali-Dyke, or similar parallel dyke running about north and south, and various indications of flowsheets issuing from the dyke, and there is little doubt that this has had some influence in causing considerable decomposition of the strata and also on the value of gold in the reefs in the immediate vicinity.

Regarding the very narrow stopes mentioned by Mr. Bell as worked in the district, he could corroborate this, as he had

crawled around practically horizontal stopes in the sandstone reef at Sabie, which were less than 18in. high, and the reef was very hard and required drilling and blasting, and it would be an object lesson to many Rand men to see how little waste rock was mined from a reef which was only 6in. to 18in. thick, with a very strong hanging and footwall.

While he was delighted to hear the description that evening which Mr. Bell had given—because he had given a very exhaustive description of the whole district—he thought the information during the 25 years of which he had spoken was very poor indeed for the amount of work, development and prospecting which had been done. The information he had no doubt was held by many, but he thought, if published, it would be greatly to the benefit not only of the district itself, but to the mining community of the country.

The President was pleased that the discussion had begun so well, and thought they should be greatly obliged to Mr. Bell for his paper. Mr. Bell, by reason of his intimate knowledge of the district, obtained through several years of exploration and prospecting, was particularly suited to speak on this subject. In these depressing days it was refreshing to hear of so many gold reefs spread over such a vast country, and over so many horizons. He thought that perhaps Mr. Bell did not describe the delightful climate sufficiently, the natural beauties of Pilgrims Rest district, and the facilities provided by nature for cheap mining by the small man and syndicates. He hoped this would be the beginning of a valuable discussion on the district. He thought Mr. Bell might have enlarged on the minerals found in the various reefs. He would refer members to a paper on the metallurgy of the district by Mr. Robert Lindsay, published in our *Journal* in April, 1917, which he thought might be read as complementary to the paper of Mr. Bell. These two, and the Geological Survey Memoir No. 5, referred to, would give the reader an excellent idea of the district from a geological, mining and metallurgical standpoint. He hoped it would be the means of creating renewed interest. Its many gold reefs were the bread and butter of the miner of the district to-day, and he hoped they would be the inspiration and the livelihood of the generation of tomorrow.

COAL PILLAR EXTRACTION FROM TWO SEAMS, AND SURFACE EFFECTS.

BY WILLIAM TAYLOR HESLOP,
M.I.M.E., F.G.S.

(*Printed in Journal, October, 1921.*)

DISCUSSION.

Mr. J. A. Woodburn: When I was listening to Mr. Heslop's paper last month I was reminded of similar problems in Lanarkshire, Scotland, twenty-five to thirty years ago.

There were in Lanarkshire at that time seven or eight workable seams in the same colliery, and the Pyotshaw and Main seams had from 5ft. to 15ft. of rock intervening, and the Splint and Virgin seams had even less rock between the beds of coal, and the management at that time, in many collieries, had their own methods of working, and many discussions arose as to the best and most economical.

Evidently the method described by Mr. Heslop is a Stoop and Room or Pillar and Stall method, but in Scotland the Longwall system gave place to the Stoop and Room method under these conditions long ago, and all the modifications of working were variations of the Longwall system.

My memory of the method employed was that the lower seam was worked first, and the upper seam was worked immediately afterwards, the face of the upper being not far behind the face of the lower, and the same main roadways were used for both seams.

I have referred to some old transactions of the Mining Engineers on this point and have found that in June, 1902, three papers were read before the Mining Institute of Scotland on "The Working of Contiguous or Nearly Contiguous Seams of Coal," and a perusal of these papers would, no doubt, be of great interest to Mr. Heslop, who says he studied the South Staffordshire methods, but could not get the help he wanted there.

In the first of these papers, by Mr. John Hogg, he describes the working of the Pyotshaw and Main Coals, where anything up to 12ft. of Dark Fakey Blaes, with sandstone ribs, intervene between the two seams, and he summarises in the following remarks: "It appears that, where the intervening strata exceed 6ft. in thickness, it would be more profitable to work the Pyotshaw seam first, and where the strata are 6ft. or less

in thickness the Main coal should be worked first.

"The Pyotshaw is the upper, and the Main is the lower seam, and each is about 4ft. in thickness."

In the second paper, by Mr. Thomas Moodie, the following remarks were made:

"The lower seam was worked first on the Longwall principle, leaving the upper seam as a roof for these lower workings.

"(2) The working of the under leaf is carried forward a distance of 600ft., or thereabouts, and then the upper leaf is worked back, and the same roads being used as in the under working.

"(3) These seams have at places been worked both in advancing order, the first working-face being kept about 90ft. in front of the second working-face, a system which is perhaps advisable where the roof above the upper seam is firm and strong. But simultaneous working on the same road is objectionable if the roof be soft."

These remarks apply to two seams being worked in Fifeshire.

Dealing with the Main and Pyotshaw seams in Lanarkshire, the following remarks were made:—

"Where the intervening strata are 2ft. thick pillars are formed in the Main Coal seam on the usual Stoop and Room system, propping up the midstone in the openings made in the Main Coal seam. The pillars measure 100ft. square, and it is necessary to exercise great caution while stoops are being removed."

For a while the hardness next the pavement was the despair of the miners, and was a matter of great perplexity to the management, leading to the adoption of compressed air coal cutting machines and a change of the method of working from Stoop and Room to the Longwall system.

The method of working the Pyotshaw (upper seam) and forming the roadways is as follows:—

The roads which were formed in the first working (lower seam) are suitable for bringing back the Pyotshaw seam in the second working, and this is done without any further building in the second working.

The third paper is by Mr. Thomas Arnot, and deals with the Splint and Virgin seams, which have a section somewhat as follows:—

Splint Coal: 3ft. 8in.

Blaes: 6in. to 6ft

Virgin Coal: 2ft. 4in.

Regarding the method of working, he

says: "Where the two seams were first found together a small district was opened out on the Longwall method, working both seams, but it was soon found that this method could not be continued owing to the soft nature of the roof lying above the Splint seam."

And he winds up his remarks by saying: "Where two seams similar to those above described occur together in a sufficiently large area, it would be the best method of working to take the lower seam first, but no difficulty has been experienced in working the Virgin seam after the Splint coal has all been extracted."

It appears to the writer that the inauguration of the Longwall work in Natal would not only be a safer and simpler method, but would enable more round coal and therefore less dross to be produced, which would, no doubt, add to the value of the output as a whole.

It is always a difficulty to any manager to start an entirely new method of working to that which has been an established custom, but one section of the mine might be selected and a trial made, and after a few months the men and boys working in this section would get familiar with the altered conditions and gradually the improved efficiency would be apparent, and lead to the adoption of the system in the whole area.

In Stoop and Room or Board and Pillar work the roof cannot be controlled with anything like the regularity of Longwall work, and that is the real benefit got by the change, and experience would soon determine the distance apart between the working face of the lower seam and that of the upper seam being worked behind.

If the sandstone between the two seams were ripped down in the roadway and used as building packs the roof of the lower seam would gradually settle on these packs and reduce the distance to the roof of the upper seam, which should be easily mined owing to the pressure of the bending strata.

The distance the face of the upper seam was allowed to lag behind would be determined by this pressure, as too much cantilever might nip the coal and make it too tough, and too little cantilever would make the two workings of too great a height, so that the economical distance would have to be arrived at from practical experience, but I feel certain the Longwall method of extracting both seams, the lower first and the upper seam after, would be a better and

more economical method than the Piilar and Stall method of working.

Mr. Heslop's remarks *re* cantilever pressure are most interesting, and now that the Rand mines are reaching such great depths, although the strata in these mines are exceptionally hard compared with coal strata, yet the same evidences of cantilever pressure is now being observed, and the same principles apply, the only difference being one of degree, and Mr. Heslop's remarks should be carefully studied by all Rand Mining men.

The meeting then terminated.

Notices and Abstracts of Articles and Papers.

CHEMISTRY

SALTS REFINING PLANTS AT OWEN'S AND SEARLE'S LAKES.—The following is an abstract of a report on the methods of production of soda ash, borates and potash from these lakes in California. Owen's Lake is the principal source of natural carbonate of soda, while Searle's Lake produces considerable potash and borax. The amount of recoverable alkali is not unlimited, but is sufficient to meet demands for many years. Owen's Lake is approximately 13 miles by 8 miles, with a rate of evaporation of 10 in. per year. The quantity of salts contained in its brine is estimated to be, in million metric tons: Na_2CO_3 46.6; NaHCO_3 11.08; Na_2SO_4 19.1; NaCl 51.5; KCl 5.53; $\text{Na}_2\text{B}_4\text{O}_7$ 3.55.

Analysis of Owen's Lake Water.

Sp. gr.	1.222 at 15.5° C.
Total Salts	25.53)
H_2O	74.47)
Na_2CO_3	8.32
NaHCO_3	1.85
Na_2SO_4	3.77
NaCl	9.87
$\text{Na}_2\text{B}_4\text{O}_7$	0.61
KCl	1.08

Searle's Lake is situated in a basin, of which it occupies the centre depression. This is approximately 12 sq. miles in extent. Its surface is composed of quite pure sodium chloride. Beneath this is the "crystal body," a coarsely crystalline deposit containing a large variety of alkali minerals. The crystalline deposit is from 65 to 75 ft. in depth, and is saturated to within a few inches of the surface with a brine of the following composition:

NaCl	16.54
KCl	4.82
Na_2CO_3	1.82
$\text{Na}_2\text{B}_4\text{O}_7$	1.50
Na_2SO_4	7.16
H_2O	65.16

"This brine is estimated to occupy from 20 to 40% of the volume of the crystal body. Its KCl content is estimated at eight million tons and the borax content at four million tons. This does not include any salts that may be added to the brine through solution from the "crystal body."

"Production at Owen's Lake is largely confined to that of carbonate of soda. At one recovery plant brine from the lake is pumped into a series of solar evaporating ponds in the spring. The brine as it becomes concentrated in the first pond by evaporation is run into a second pond of the series, the first pond being again filled with fresh brine. This is continued until a sufficient amount of sodium carbonate is contained in the ponds to give the season's crop of trona. Toward the winter the nights become cool and sodium carbonate and sulphate crystallize out as decahydrate. When this is complete, the mother liquor is drained off and the resulting trona is harvested. It is, after air drying, melted in a furnace. The molten carbonate runs in a thin stream into a blast of air which produces a globular product analysing 55% Na_2O ; less than 25% Na_2SO_4 , and a small amount of NaCl. Another plant, after solar evaporation of the brine to saturation, pumps the liquor to a carbonating tower, precipitating sodium bi-carbonate; the crystals are separated by filtration, air dried and melted in a furnace, producing sodium carbonate, which is ground and screened.

"At Searle's Lake brine is obtained from wells drilled in the salt body. This is fed to triple effect evaporators, and a hot solution concentrated with respect to KCl is obtained. This is cooled rapidly, first with raw brine and then by refrigeration and a crop of KCl crystals produced. The crystals are separated from the mother liquor in centrifugals. This refined potash contains 92.81% KCl and 3.98% water.

"Another process used at Searle's Lake has as distinctive features the use of solar evaporation and fractional crystallization at different concentrations and temperatures, the brine being so manipulated that the various salts are deposited in different ponds."—L. W. CHAPMAN, *Chem. and Met. Engineering*, April 20, 1921, p. 683. (F.W.)

LOW-GRADE CYANIDE.—Low-grade cyanide manufacture by the American Cyanamid Co. at Niagara Falls is coming into general use in the Cobalt district, Ontario, and to some extent is replacing the higher grade article manufactured by the Cassel Cyanide Co. of Glasgow, Scotland. The reason given for using the low-grade material is a saving in costs which more than compensates for the added inconvenience.—*Min. and Scien. Press*, August 21, 1920, p. 288. (C. J. G.)

TREATMENT OF PHOSPHATES BY CALCINATION WITH A VIEW TO THEIR EMPLOYMENT AS PHOSPHATIC FERTILISERS.—(1) Process (Wolter Phosphate).—At least $1,200^\circ\text{C}$. 100 parts of phosphorite, 70 of acid soda sulphate, 20 of calcium carbonate; 22 of sand, and 6 to 7 of carbon are melted. The product when cooled is broken up, desiccated and pulverised. (2) Process (D.R.P. 240875).—Crude phosphate is melted at $2,000^\circ\text{C}$. until a test piece when cooled, pul-

verised, and treated with diluted SO_4H_2 coagulates albumen. (3) Process (D.R.P. 274409) (Phosphate Rhenania).—Phosphorites reduced to fragments are mixed with silico-potassic rocks, heated in special furnaces, without attaining melting point, until all hardens. (4) Process.—Phosphatic substances are melted with a certain amount of lime and silica so as to obtain the combination $5\text{CaO} \cdot \text{P}_2\text{O}_5 \cdot \text{SiO}_2$. (5) Process.—Crude phosphates are heated with CaCl_2 or MgCl_2 . The HCl liberated solubilises the phosphate. (6) Process (D.R.P. 258790).—Crude phosphate is melted with artificial silicates. The fused mass obtained is pulverised by aid of a current of steam. (7) Process.—Tetraphosphate (Italian invention) is obtained by calcination or finely pulverised phosphates with which 6 per cent. alkalino-terreous carbonate is mixed. (8) Process.—The phosphoric acid of natural phosphates is made soluble in citrate by moderate heating with carbon, lime, wood, or petroleum. (9) Process (D.R.P. 715587).—Mixtures of phosphates of alumina are calcined at a temperature of at least 1150°C . with magnesia, in such proportion that a molecule of P_2O_5 will correspond to four molecules of MgO .—*Chimie et Industrie* (July, 1921) through *Chemical News*, September 16, 1921, p. 155. (H. R. A.)

ACTION OF LIME IN MAGNESIUM OXYCHLORIDE CEMENTS.—Plastic calcined magnesite differs from dead, burned or metallurgical magnesite in being burned at a much lower temperature. Dead, burned magnesite in which periclase formation has gone on to a greater or less extent, does not react with magnesium chloride. The material now in use by the oxychloride industries is prepared by calcining any reasonably pure natural magnesite at a temperature of 700 to $1,000^\circ\text{C}$. The commercial product is a white or light-coloured powder containing 75 to 78% MgO , 5 to 7% SiO_2 , 5 to 6% CaO , and 1 to 2% R_2O_3 .

Efforts have been made to regulate the quality by specifications based on chemical analysis, but it has been found that inferior as well as good calcined magnesite will meet these specifications. The industry is disposed to accept specifications based on physical tests only.

The analysts' report of the presence in calcined magnesite of a definite amount of lime is meaningless unless the form in which it occurs is also specified. Marble dust or limestone powder is sometimes deliberately used as an aggregate without any harmful effect on the properties of the cement, such forms of calcium carbonate acting merely as inert material. It is well established that the addition of calcium oxide to an oxychloride mix markedly diminishes the strength of the resulting cement.

Many analyses were conducted to ascertain the Active Lime content, this term being applied to lime in any form which exerts an injurious effect on the cement.

The "water soluble" method using phenolphthalein as indicated proved to give higher results on magnesite which had been calcined at temperatures below $1,000^\circ\text{C}$. than when the temperature of calcination was higher than

this.

A much higher alkalinity result was obtained when a 5% solution of sodium chloride was used in the test, when a larger difference was observed between the phenolphthalein and the methyl orange end points.

The free lime (CaO) does not necessarily comprise the total of the so-called active lime in the material, as the addition of small quantities of precipitated calcium carbonate has been proved to reduce the strength of the resulting oxychloride.

The following method is considered to give results more closely indicating the Active Lime content of the calcined magnesite: 2.5 gm. of the sample is agitated with 300 c.c. of 0.75% magnesium chloride for twenty-four hours. The solution is made up to 500 c.c. filtered and the lime determined in an aliquot portion of the solution by double precipitation as oxalate.

It is proved that a definite relationship exists between certain physical properties of oxychloride cements and active lime content of the calcined magnesites as determined by the stated magnesium chloride method.

Tables are given showing this relationship, including the figures of analysis, also the objectionable effect of calcium chloride added to the magnesium chloride solution.—MAX Y. SEATON, CLAUDE R. HILL and L. C. STEWART, *Chemical and Metallurgical Engineering*, Aug., 1921, p. 270. (H.D.B.)

THE PRODUCTION OF SULPHATE OF AMMONIA FROM COAL, WITH A DESCRIPTION OF THE WORKS OF THE NATAL AMMONIUM, LTD.—The coal of the district is in general semi-bituminous, but at the Ngwibi Mine it is almost anthracitic, and contains an exceptionally high percentage of nitrogen, averaging about 2.2%.

This coal is crushed to 1½ inches, that finer than quarter of an inch being rejected. The coal is gasified in gas producers of the Mond type, the temperature is kept low as possible to obtain the maximum ammonia recovery, which is given at 65 to 68%.

There are eighteen producers in operation, each of which consists essentially of a steel cylinder separated by a space from an inner brick shell. The outer cylinder tapers to a conical bottom provided with a sliding door for removal of cinders. The inner cylinder is built of fire-brick and does not reach the bottom of the outer cylinder, but ends in an iron ring from which fire-bars slope downwards to a smaller diameter ring to form a hanging grate.

In operation, hot air saturated with steam at 82° to 85° centigrade is forced into the annular space between the producer proper and the steel shell, where it is raised to 150 to 180 centigrade, and impinges at a pressure of 60 c.m. of water upon the bottom of the fuel bed at the grate bars.

The gas passes through recuperators or superheaters, then through a washer containing water, when it is cooled to about 90° C. The water removes sulphur and cyanogen compounds, but very little ammonia; this is periodically distilled and its ammonia content passed into the saturator.

From the washer the gas passes through a spray arrester to the saturator, where 97 to 98% of its ammonia is recovered by means of

sprays of ammonium sulphate liquor containing 2% of free sulphuric acid.

This liquor, when sufficiently concentrated, is evaporated, the resulting crystals of ammonium sulphate are centrifuged, dried and bagged.—OSCAR LAZAR, B.S., Eng. (S.A.), *Journal of the S.A. Association of Anal. Chemists*, January, 1921, p. 13. (H.D.B.)

A NEW FORM OF CARBON: CARBON FORMED BY THE ACTION OF MERCURY ON CARBON TETRACHLORIDE, TETRABROMIDE AND TETRAIODIDE.—By the action of mercury vapour on carbon tetrachloride at 600 to 700°, mercurous chloride is formed and carbon is deposited. Under high pressure, 900 to 2,760 kilos per sq. cm., the reaction starts at about 400° and is accompanied by a fall in pressure. Carbon tetrabromide and tetraiodide react similarly. The carbon so formed retains water tenaciously, 7 to 10% after heating at 600° in a stream of nitrogen. The density of the carbon so obtained is high, 2.32 from carbon tetrachloride, 2.51 from the tetrabromide, and 2.37 from the tetraiodide, whilst that of graphite is 2.1 to 2.3. Carbon obtained similarly from hexachloroethane had $d=2.16$, from hexachlorobenzene 2.46 to 2.22, and from carbon disulphide 2.38. It appears that carbon formed by reactions not involving the formation of water has a higher density than that which is formed with water. On keeping, this dense form of carbon absorbs much water, and, when it is again dried its density is found to have diminished. When carbon from carbon tetrachloride is heated for a short time at 2,100° to 2,300°, its density falls from 2.32 to 1.37. Chemically the new, dense form of carbon is more reactive than sugar carbon (compare this vol. ii., 451). X-ray examination failed to reveal crystalline structure, whilst sugar carbon appears to be, to some extent, crystalline. The high density of the new form of carbon is probably due to very close packing of extremely small particles. Heating to a high temperature causes the particles to increase in size, with the result that the density decreases, without the appearance necessarily of a crystalline structure.

The condition diagram of carbon is discussed. The melting-point curve of graphite probably falls with increasing pressure, cutting the diamond curve near 1,500°. The density of liquid carbon would then be greater than that of graphite. It is suggested that above the diamond field, at high temperatures and pressures, an unknown form of carbon exists, the density of which lies between that of graphite and diamond. Such a condition diagram accounts for the known properties of diamond and graphite and for the geological facts.—G. TAMMANN (*Zeitsch. anorg. Chem.*, 1921, 115, 145-158) *Journal Chemical Society*, July, 1921, ii., p. 470. (H.A.W.)

THE ALKALI CYANIDES—Methods have been devised for preparing the hitherto unknown cyanides of lithium, rubidium and caesium in a pure state. *Lithium cyanide* was prepared by shaking a suspension of finely crystalline, dry lithium hydroxide in ether with anhydrous hydrocyanic acid. The cyanide is extremely soluble in water and resembles sodium and potassium cyanides in its properties. With

silver cyanide it forms *lithium silver cyanide*, $\text{LiAg}(\text{CN})_2$, colourless crystals, which in aqueous solution does not react with hydrochloric acid, hydriodic acid, or disodium phosphate, but does so with hydrogen sulphide. *Lithium ferrocyanide* was prepared from hydroterrocyanic acid and lithium carbonate. It forms bright yellow crystals containing $6\text{H}_2\text{O}$, differing in this respect from the sodium salt. *Lithium ferricyanide*, prepared from silver ferricyanide and lithium chloride, is less soluble than the ferrocyanide, and forms an orange-red crystalline powder containing $4\text{H}_2\text{O}$. *Rubidium cyanide* is very soluble in water, but is not hygroscopic; it is insoluble in alcohol and ether. It forms the double salt, $\text{RbAg}(\text{CN})_3$, with silver cyanide. *Rubidium ferrocyanide* crystallises with $3\text{H}_2\text{O}$, and the *ferricyanide* and *manganicyanide* form anhydrous crystals, these salts being probably isomorphous with the corresponding potassium salts. *Cesium cyanide*, and the salts $\text{CsAg}(\text{CN})_2$, $\text{Cs}_4\text{Fe}(\text{CN})_6$, $3\text{H}_2\text{O}$, and $\text{Cs}_4\text{Fe}(\text{CN})_6$ were prepared and found to have similar properties to the corresponding rubidium salts.

All the alkali cyanides are hydrolysed by water and smell of hydrocyanic acid when exposed to the air. Determinations of the degree of hydrolysis at 18° and 25° in aqueous solution at dilutions from N to $N/10$ were made by measuring the rate of hydrolysis of methyl acetate. All five alkali cyanides were found to be hydrolysed to the same extent, namely, about 1.25% at 25° in $N/10$ solution, or 0.4% in normal solution.—JULIUS MEYER, (*Zeitsch. anorg. Chem.*, 1921, 115, 203-217), *Journal Chemical Society*, July, 1921, i., p. 501. (H.A.W.)

METALLURGY.

THE EROSION OF BRONZE PROPELLERS.—The results of twelve years of research on erosion of bronze propellers are summarised. The investigations were started in 1908, owing to the serious position created in connection with high speed liners, destroyers, etc. Further speed developments were limited by this factor of propeller erosion. A complete account of the investigations is given along with several macro and micro-photographs. The conclusions reached are that chemical and galvanic effects are negligible and that the true causes of deterioration are mechanical, viz.:—

(a) The frictional rub of the water.

(b) The impinging on the propeller blades of water broken with evacuated spaces which subsequently collapse, giving what is called the "water-hammer" effect.

On establishing the cause of erosion the problem was to find alloys which would be as mechanically sound as brasses consisting of crystals of the α type, but which would be as resistant to wear as β type brasses, which were not workable.

Alloys with the required structure and properties were obtained by substituting for a small part of the zinc small proportions of such metals as manganese, aluminium, iron, etc.

A typical manganese bronze of this type contains Cu 55.16%, Zn 13.0%, Al 0.27%, Mn 1.12%, Fe 1.11%.

The *Mauritania*, whose first propellers were worn out after three months' running, was fitted with manganese bronze propellers, and ran six months without sign of propeller erosion.

Manganese bronzes of the type developed are now used throughout the world for high speed propeller work.

A very complete reference list to the numerous publications on this subject is given in the paper.—O. SIMBERRARD, Ph.D., *Journal Soc. Chem. Ind.*, page 38 T., February 28, 1921. (H.R.A.)

VACUUM CONVERTERS.—Metallurgical experts are claiming that the idea of a vacuum converter has now been definitely proved of practical value and must be reckoned with in the future of the steel trade. Steel made by the ordinary process is understood to contain from five to ten thousand times its own volume of gas. This gas is given up to a greater or less extent on the steel attaining the melting-point, while conversely steel cooling down from the melting-point re-absorbs these gases, and they are held more or less loosely when the ingot solidifies, thereby producing varying degrees of unsoundness. To prevent this condition experimenters have been working along the lines now known as the "Vacuum Converter Press." The charge to be converted is melted by the generation of heat, usually electric, inside a vessel. When the contents are thoroughly fluid the vessel is connected to a vacuum pump, which draws out the gases remaining; the vacuum is sealed, and the steel cools without being able to re-absorb; hence the ingot produced should be wholly sound. Razor steel made by this process is said to have proved of unusually fine quality, and it is predicted that it will find a market for all high grades of cutlery steel. The cost is less than that of crucible steel.—*Ind. Aus. and Min. Stand.*, September 15, 1921. (C.J.G.)

MINING.

MEASUREMENT OF AIR VELOCITIES.—Mr. James Cooper, of the Heriot Watt College, Edinburgh, read a paper before the Mining Institute of Scotland on "Measurements of Air Velocities and the Testing of Anemometers." At the outset the author said that the two best known methods of measuring air velocity in mines, namely, by the anemometer and by means of smoke, were both liable to serious error. As had been frequently noticed, smoke travelling in an airway of uniform section was subject to a decrease of velocity as it passed onwards from the point of ignition; in the central part of the roadway it was affected by eddies, and at the sides it clung to damp surfaces and was seriously impeded by timber. If the sectional area of the road varied, the results obtained by smoke were still more faulty. Because of the friction of its parts, the anemometer, too, could only yield an accurate result at one velocity; at all others accuracy could only be achieved by correcting for the influence of

friction, and at low velocities the correction might be greater than the speed registered by the instrument.

The main purpose of the paper, the author went on to explain, was to discuss the results

furnished by the testing "table" that had been installed at the Heriot Watt College, Edinburgh, and to compare them with those obtained in other ways. It was velocities below 300ft. per min. that the need for calibration became most imperative, and it was especially at those low speeds that the effect upon the instrument of wear and rough handling was most pronounced. The "table" might be regarded as a development of that described almost sixty years ago by Messrs. J. J. Atkinson and J. Daglish (*Transactions, North of England Institute, Vol. X.*). It has been designed by Dr. Henry Briggs, of the Heriot Watt College, Edinburgh. The whirling rod on which the meter under test was mounted was rotated by means of a leather sewing machine belt, quarter of an inch in diameter, from a special driving gear. The variable speed gear, which was worked from a shunt wound motor through a worm and worm wheel, was of the epicyclic type. The vertical bevel wheels were carried round at constant speeds; they engaged with horizontal bevels, of which the latter was in one piece with the brake wheel. The brake was a motor-cycle belt and was adjusted by a screw and handle. Motor and gear were mounted on a wooden frame, occupied little space, and were very portable. The framework on which the whirling rod and small motor was mounted was also designed to be portable, so that the apparatus could be moved aside after completing a test. The rod was Chesterfield steel tubing of 21 gauge, 2in. diameter, 12ft. in length, and weighed 8lbs. It combined lightness and rigidity. A simple clamp fixed the meter to any part of the rod.

A novel feature of the apparatus was the manner of operating the meter trigger or clutch, while the meter was being carried round on the rod. To ensure accuracy in calibrating an anemometer it was essential that the meter be moving at the selected speed before the counting mechanism was put into gear, and also that after the lapse of the required interval the mechanism should be thrown out of gear while the meter was moving. This entailed using some means which could be instantaneously operated from outside the radius of the moving rod, and it was decided to adopt an electrical device in order to secure the instantaneous action required. A small motor was mounted on the brass table and a light drum, three-quarters of an inch in length by half an inch in diameter, fixed to the motor shaft. A thread was passed from the meter trigger round the drum in a single loop, thence to a small pulley fixed on the meter clamp and back to the trigger. The motor was shunt connected and took current from a four-volt battery working through a switch with forward, off and reverse positions. The motor terminals were connected to three contact brushes running on a three-ring disc, and the fourth wire connected to the vertical shaft. The rings and shaft were in turn connected to the reversing switch.

The arrangement was found to work perfectly, and in numerous tests the results had been recorded throughout with no failure of action of the motor, the trigger in all cases acting simultaneously. Numerous tests had been carried out on this anemometer table,

and the figures obtained from the experiments had been compared (1) by observation of smoke velocities, and (2) walking tests with the meters over a measured straight line in a still atmosphere. The meters used were of the Biram type, this being the instrument most in favour in the mines of Scotland.

The first series of tests carried out was to discover what influence, if any, would result by fixing a meter on the rod at different radii. These radii varied between 6ft. 6in. and 1ft. It was to be expected that at short radius, where the whirling anemometer was not moving through the air at a uniform velocity at all points of its width, the results as indicated by the instrument would be affected thereby, and the tests proved this to be the case.

The differences in the corrections got from the results obtained by placing the meter at different radii on the whirling rod was so considerable that it was deemed necessary to enquire into the reason for that difference. Dr. Briggs suggested that the effect might be explained from the fact that the impact of the air across the width of the fan differed most with the small radii. The following explanation was suggested by the author: The probable effect of air striking the vanes of a meter was to set up certain stream-lines passing on either side. The deflection of these stream-lines tended to create a partial vacuum behind the vane. By varying the position of the meter, *e.g.*, at different radii on the whirling rod, the stream-lines deflection would vary and, according to the results of the experiments described, the vacuum effect seemed to increase as the circle of travel decreased. The chart correction was practically uniform for all radii at 500ft. velocity. The vacuum effect seemed to stabilise at this point, and the meter moved through a path of uniform stream-lines.

In using an anemometer table the problem was one of considerable importance, and was closely bound up with the general principles of aerodynamics.

The writer passed on to describe a series of tests which were carried out to obtain charts for different sizes of instruments. A 6in. and 1in. meters of similar design were used, while two at 2½in. of the usual design were also included. The four anemometers tested were all in regular use, one 2½in. and the 6in. at the Heriot Watt College, and the 1in. and the second 2½in. at collieries. The radius selected at which to place the meters was 5ft. 5in., giving 34ft. circumference of travel, and the speeds recorded ranged from 50ft. to over 2000ft. per minute. As the first-mentioned velocity was very low for anemometer reading it was found during the tests that only instruments in good working order would give satisfactory results at that speed. Of the four anemometers tested the 1in. and 6in. meters only yielded consistent figures at this low rate of speed. This was probably due to the former being a new instrument and the latter only lately overhauled.

The results given by the two small instruments were unreliable and required unworkable large corrections at low speeds. When a velocity of 500ft. per min. was reached the corrections for all four instruments were fairly uniform and remained so up to the maximum velocity of over 2000ft. per min.

An interesting point in connection with these experiments was that although the charts plotted from the tests were similar in form to those sent out by the makers of the instruments, the figures of correction varied widely. This was particularly so at low speeds, and also at the recorded velocities of crossing the line of zero correction. The errors associated with the use of smoke as a means of measuring air velocity were thoroughly investigated many years ago by Messrs. J. J. Atkinson and J. Daglish. After a series of tests, in which the velocities of air currents were determined in a smooth-sided experimental gallery, first by the four calibrated anemometers already referred to, and then by means of smoke, it only required to be said that the latter method proved unreliable. It had achieved a spurious importance of late years due to its introduction into the mine firemen's examination; but for that it would probably have passed into the oblivion it so well deserves.

The last series of tests taken was to calibrate the anemometers by holding the instrument in the hand and walking in still air over a measured distance. A suitable place for this purpose was found in the observation court at the mine rescue station of the Heriot Watt College. The procedure adopted was as follows: A straight path of 66ft. in length was measured, and timed readings of the instruments taken over the distance. A few paces were traversed before the starting point was reached; then the meter and stop-watch were thrown in gear simultaneously. The distance was traversed in times varying from 5 seconds to 40 seconds. When low velocities were being measured in this way the inertia of the older instruments required to be overcome by a tap at the start; the vanes would then continue to revolve throughout the measured distance. The carrying out of these walking tests had the obvious difficulty of getting a sufficiently long straight path in still air. In the writer's tests, had a longer distance than the 66ft. been taken it would have involved turning through several sharp bends, and errors of unknown magnitude might have resulted from the frequent change of direction. The lowest speed selected was that just sufficient to cause the vanes to revolve. This was obtained when walking at a speed of 99ft. per min., and at this rate the reading in the two small anemometers was about 30ft. per min. This resulted in a plus correction of over 200ft. per 100ft. per min.

The value of this series of tests was a measure of the approximation of the correction curves to those obtained from the whirling rod; and in a comparison of the plotted results from both series, it was to be noted that the values were fairly consistent. This conclusion was one of value, for, given a straight path in still air and a reliable stop-watch measuring to 0.2 sec., it was seen to be possible, without more elaborate mechanism, to determine the correction curve for an anemometer for speeds up to 500ft. per minute with a degree of precision sufficient for ordinary purposes.

The results obtained in these tests indicated the unreliability of the anemometer when measuring low air velocities. JAMES COOPER, *Colliery Guardian*, page 1072, October 14, 1921. (J.C.)

THE MAGNETOMETER.—The original Swedish mining compass called the dipping needle has

been superseded by a sensitive instrument called the magnetometer. In the hands of experts this instrument gives reliable data regarding the presence of, the dip, the depth and the strike of ore bodies.

Magnetic minerals are classified into attractive magnetic and retractile magnetic. Magnetite and pyrrhotite are attractive, and like tempered steel, retain magnetism when once magnetized. Hornblende and pyrite are retractile, and like soft iron, become magnetic when attracted by a strong magnet. When mixed with attractive magnetic minerals they become magnetic, and extend a greater influence on a magnetic needle. A deposit of magnetite and pyrite has a much stronger influence on a magnetic needle than a deposit of pure magnetite.

Observations made by experts in the use of the magnetometer enable charts and fairly reliable surveys to be made particularly of hidden iron ore bodies. Gold does not influence the needle, although pyrite and black iron deposits of placers do. Magnetometric investigations are particularly valuable for ascertaining the position and extent of iron ore deposits; also for picking up extensions of mineral deposits in hard rock formation that have been displaced or faulted.—A. Gimsox, *Mining and Scientific Press*, page 437, September 24, 1921. (F.W.)

GUNITE IN INCLINED SHAFTS.—The Calumet and Hecla conglomerate has been mined very largely through inclined shafts, the inclination being from 35° to 40°. Shortly after driving of the main tunnel had started, "slabbing" began on a very extensive scale. There were no "air blasts" and no big caves, but ground that had been carefully barred for loose would again become dangerous, frequently in a few days. This finally became so serious that it was realised that the expense of timbering, with the probable continuous upkeep cost, might jeopardise the success of the entire plan. It was therefore decided, state J. Knox and O. Potter ("M. C. M. Alumnus"), that gunite would be tried, and in February, 1919, several hundred feet of tunnel were "gunned." "Slabbing" stopped at once and the cement remained unbroken. The only thing that happened, however, was that, due to the gunite being put on all in one coat, it was a little too thick in spots and before the cement had time to set properly, the weight of the material itself pulled the gunite away from the rock, leaving occasional air spaces. This formed a sort of blister, which finally resulted in small slabs of cement falling off and again letting the air and moisture reach the rock. In later work this difficulty has been entirely overcome by putting on two thin coats—usually one coat on one shift followed by another coat on the succeeding shift. Up to December 4, 1920, 8,722 feet had been "gunned," and there is not a stick of timber being used in any part of this completed portion for the purpose of supporting loose ground. Nor are there any cracks showing which would indicate that we may expect any difficulty in the future from this source. It is not, however, proof against severe "air blasts." A series of very severe "blasts" last spring loosened and cracked portions of the gunite for several hundred feet, and it was necessary to trim and "gun" this

area again. There was no question as to the cause of the trouble, however, and the expense of repair was very small compared to the cost of repairing a timbered drift under similar conditions. At the present writing two conclusions seem obvious—first, that the cause of a great deal of the "slabbing" or caving of the walls of shafts and other openings is not thoroughly understood; and second, that "gunning" is certainly a very effective and relatively inexpensive retardant for many of these disturbances. The gunite mixture used consisted of $2\frac{1}{2}$ parts of sand to 1 of cement. The sand was screened through a 3-16th inch mesh. Air pressure used was 65lb. Water pressure, 40 to 50lb. There were four men used each shift on "gun" work—two charging the gun and two men who alternated at the nozzle. These men did their own barring and trimming and applied one coat of gunite over a length of 50ft. or 9ft. by 12ft. tunnel—for an average of $6\frac{1}{2}$ lineal feet per man per shift for a double coat. The average thickness of one coat varies from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. on a smooth rock surface. Crevices and hollow spots are, of course, filled, and here the thickness of coat varies a great deal. About 25,000lb. of gunite mixture are used to complete 100ft. of tunnel. Approximately 20% of the sand rebounded from the rock and fell to the floor. This is, of course, wasted. Wire mesh re-inforcing was tried at first, but was very expensive, difficult to apply, wasteful of gunite, and finally found to be entirely unnecessary. It proved convenient to dry and mix the sand and cement on surface and to bring it to the operators in packages, each of which contained a full charge for the gun. However, when this plan was followed it became necessary to add a very small quantity of water when mixing in order to prevent a separation of sand and cement during transit.—J. KNOX and O. POTTER, *The Colliery Guardian* (M. C. M. Almanac), September 2, (J.C.)

MINE FIRES EXTINGUISHED BY SEALING.—According to D. Bunting in a paper to be read before the American Institute of Mining and Metallurgical Engineers, 90% of mine fires can be ascribed directly or indirectly to the ordinary miner's open lamp. Other causes may be smoking, electrical installations, gas explosions, gas heaters, and the communication of fire to the outcrop from ash dumps, culm banks, timber and brush fires. Generally mine fires may be divided into two classes. Those occurring in inaccessible workings and those occurring in accessible workings. The methods pursued in extinguishing or controlling mine fires are as follows: (1) Direct attack; (2) smothering by sealing; (3) flushing with silt or other solid; (4) flooding with water; (5) cutting off; (6) surrounding with incombustible materials; (7) dragging out by stripping from the surface. The regulation of the air supply to the fire area is of prime importance, as too much air will generally increase the extent of fire and too little will increase the liability of explosion. The speed of travel of a mine fire is dependent on the conditions in the immediate vicinity of the fire. With dry timber and a strong continuing current, a fire will make rapid progress, while in coal, the progress is extremely slow, except where there is communication with

an overlying vein through caves and broken ground. The most practical, and probably the most efficient, means of direct fighting is with water directed in hose streams of good pressure and capacity, which can only be secured by providing pipe lines of adequate capacity. A system of water-pipes, standardised as far as possible, should be maintained for immediate use in mines liable to fires, and maps giving the location of these lines should be provided periodically to the colliery officials. The pipe, hose, connections, valves, wrenches, nozzles, etc., should be maintained at definite points of convenience. In the sealing of fires, the conditions favourable to this method are limited area of workings to be sealed and minimum number of seals required. The unfavourable conditions are extensive workings, and caved workings with liability of connections through cracks and crevices to overlying veins on the surface. The principal danger is the liability of explosion, which prompts the question as to whether the intake or return stoppings should be erected first. There have been many failures to extinguish fires by flooding fire areas with water, because anticlines and pockets in the workings prevented the water from submerging the fire, owing to the compression of the mine air.—D. BUNTING, *Colliery Guardian* (American Institute of Mining and Metallurgy), September 9. (J.C.)

AIR PRESSURES AND DRILLING SPEEDS OF HAMMER DRILLS.—These data were collected during a series of tests made at the property of the United Verde Copper Co. to determine the most economical air pressure for the operation of hammer drills under the varying conditions of use, and to investigate the variation in drilling speed at different air pressures. About 1-500 tests were made on 12 models of drills, at gauge pressures ranging from 10lb. to 130lb. No effort was made to bring theory and practice into accord; but rather to formulate sundry empirical rules covering the average variation of the results obtained. However, these rules on the performance of hammer drills, based on the air pressures as the main variable are not necessarily of universal application; they apparently satisfy the results obtained in this particular series of tests.

The drilling conditions at this property vary widely. An average of 21 machine shifts to a 2ft. round is necessary in some of the development work, while an advance of 56ft. has been made in seven shifts in the "oxide" ground. This wide range of conditions precludes the adoption of one type of drill as a standard; consequently almost every kind of hammer drill sold in the country has been tested during the past few years. At the present time 16 different models of drills are in use, of which two types of the heavy (150lb. to 160lb.) mounted drills, one of the light mounted drill, one stopper and two hand-plugging drills are considered as standard.

Inspection of the several tabulated results shows that:

(1) There is little or no increase in mechanical efficiency of the drills above 90lb. pressure.

(2) The distance drilled per net indicated horse power is a maximum for the jackhammer type at 90lb. and increase at a slow rate for

the other machines at the higher pressures.

(3) The average thermal efficiency is a maximum at about 95lb.

(4) The factor of desirability, while increasing as the pressure, shows a comparatively slow rate of increase for pressures above 100lb.

(5) The average drill is made to be used at a pressure of 80lb. or less, and the use of pressures much exceeding this would invalidate the present replacement agreements with the manufacturers, thereby increasing the upkeep cost.

(6) The increased breakage at the higher pressures, with the consequent greater loss of time of the drill runner in changing or repairing the machine, would tend to reduce the factor of desirability.

(7) The increased breakage of drill steel would tend to limit the pressure, although there are not sufficient data on this point to determine the maximum.

From the foregoing, it would seem that under the conditions obtaining at this property, about 95lb. is the most economical gauge pressure.—H. W. SEAMON, *Colliery Guardian*, page 735, September 9. (J.C.)

MISCELLANEOUS.

THE PRINCIPLES OF VACUUM DRYING.—The authors point out that vacuum dryers are not capable of universal application. Direct heat rotary, tunnel, spray, compartment and atmospheric drum types of dryers each have their own fields.

The advantages of vacuum drying are generally: Low cost of operation, drying at low temperatures, temperature control, cleanliness, solvent recovery when desired, elimination of fire risk, etc.

Limitations at present inherent in the system are due to the necessity for strong airtight casings, non-continuous operation except in the case of certain drum dryers, and comparatively small size of units. The governing principles of the system are: the reduction of the boiling point of a liquid under diminished pressure, and the accelerated rate of evaporation at the boiling point.

Comparatively little heat is required to raise a material to a temperature most favourable for drying, and owing to the methods of heat application employed there is a very high thermal efficiency.

The rate of removal of vapours from the vacuum chamber is of great importance, for it is to be recalled that whereas one pound of water at 212° F. forms 26.8 cubic feet of steam under atmospheric conditions, the same amount of water at 28" vacuum forms 350.75 cubic feet, and under 29" vacuum 709.3 cubic feet of steam. As the vacuum pump alone cannot cope with this volume of vapour and maintain high vacuum, suitable condensers are placed in the system. The vacuum then depends upon the vapour pressure of the condensate, and the pressure exerted by the non-condensable gases which are in the materials to be dried and in the cooling water in case a barometric condenser be used.

The steam consumption of the vacuum dryer amounts to approximately 1.25lb. for each pound of water evaporated.

For materials that produce a quantity of dust a dust collector is placed between the dryer and the condenser.

Condensers are of either barometric or surface type, and where volatile solvents are to be recovered the vacuum pump discharge is led into an expansion tank connected to a small atmospheric surface condenser allowing a recovery of 95% or more of the solvent.

Vacuum shelf, rotary and drum types of dryers are discussed in some detail, and reasons for their utilisation with different types of material are given.—C. O. LAVETT and D. J. VAN MARLE, *The Chemical Trade Journal and Chemical Engineer*, originally before the American Chemical Society, page 424. October 8, 1921. (R.A.C.)

DRY CLEANED COAL.—The main objection to coal-cleaning systems as at present in vogue is that the recovered material contains a large quantity of moisture, and must therefore be submitted to some form of drying before use.

American workers have now made experiments in connection with the separation of small coal and dirt by passing the mixture through air currents. In the machine used air as the floating medium is substituted for water, advantage as usual being taken of the varying densities of the different ingredients of the mixture.

Air is blown into a chest provided with a deck of steel cloth or silk, a multiplicity of tiny air jets is thus formed, and these on expanding give rise to a film of air on the upper surface of the deck. Stratification of the mineral mixture on this deck follows, and it is said that with a properly regulated air current the mass of material becomes almost as fluid as water, and the layers of separated minerals readily slip to their specific take-off spouts. It is shown that the refuse contains only a small proportion of carbon, while it seems that the sulphur tends to carry forward with the coal, and the phosphorus to remain largely in the refuse.—EDITORIAL, *Chemical Age*, page 419, October 8, 1921. (R.A.C.)

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THE CORRELATION OF METALLURGICAL STATISTICS.

By H. A. WHITE.

An enormous mass of statistics, comprising detailed results of mining, mechanical and metallurgical operations, is being piled up in this country. Upon the mines the figures referring to a multitude of operations are registered with considerable detail, and abstracts of these are filed by the Chamber of Mines and in various Government offices.

No doubt a large part of the vast labour involved may be justified by a consideration of the valuable comparisons which can thereby be made, but the details are so numerous and complex that in the majority of cases it is only totals, averages, and ratios that can obtain adequate consideration.

Modern statistical methods, however, have evolved powerful methods of analysis which extract from these raw masses of figures much valuable information which can be used to improve details of operations, because they enable the results of small variations to be securely ascertained and they reveal the interdependence of various factors (some of which may not previously be suspected), which affect the results of the various operations.

When we recollect the weight of deductions which has frequently to be borne by the few figures obtained as the results of experiments under more or less artificial laboratory conditions it becomes an obvious duty to ascertain from the figures resulting from actual operations on a large working scale all the facts which a proper analysis will enable us to deduce.

Although there can be no doubt that similar striking results could be obtained in the fields of mining, power production, cost keeping, and in many other directions, this paper will be confined to metallurgical results and to an exposition of suitable

methods of deriving therefrom interesting facts concealed in the usual methods of presentation. In order to give a clear idea of the scope of this paper the following concrete instance is given:—

On many mines an elaborate grading of the "final pulp" leaving the crushing plant is recorded at daily or even 8-hourly intervals, and the division may be into +60, +90, +200, -200 screen grades. Now every metallurgist is convinced that his residues are reduced by an increase in the percentage of -90 in the final pulp, and possibly a few experiments have given him some idea of the actual amounts involved.

An examination of the records will show considerable fluctuations both in the grading and the total residue values, and in some few instances will be found the reverse result of a higher residue corresponding with higher percentage of -90 product. Nevertheless an application of the methods to be outlined to all the relevant figures obtained during the period present methods have been in force will determine with certainty the most probable decrease in total residue value which can be secured by an increase of 1 per cent. in the -90 grade produced.

Now until this figure and the relative costs are known it is clear that only a vague idea of the economic limit of finer crushing can be ascertained.

In order to further drive home this matter and to emphasise the difference between "statistics" and the product of the mine statistician, the case of results of sorting may be used as an illustration.

On most mines at least monthly figures are preserved showing the surface sorting, total sorting, and mill screen values. A proper analysis of the relevant figures will

almost inevitably show that increased sorting does not produce the ordinary arithmetical effect upon the screen values, although in all theoretical discussions of this subject that effect is taken for granted. If the fact be ascertained (as in certain cases it has been) that increased sorting actually corresponds with a decrease in screen values, it is clear that the question of sorting is more complicated than is usually realised, and the correlation between sorting percentages and actual stope widths on the same mine becomes of interest.

A further illustration might be given of statistics not yet published but which might possibly prove of more value to the industry than all the Commissions yet held: this is the relation between stoping width and cost per ton of reef mined in that stope. It is probable that such figures lie buried in the masses of mining statistics and it is possible that their resurrection might prove that to carry a stope at 42" or even 48" where the reef channel is less than 18" is far from economical practice, though the more usual methods of referring costs to the ton of rock mined might conceal the true facts.

To Professor Karl Pearson the scientific world is deeply indebted for the method of correlation and various developments of the modern critical apparatus for the examination of statistics, even though some of his ideas find a source in the writings of Bravais and Galton. Much work has also been done by G. Udny Yule, W. Palin Elderton, Prof. Edgeworth, W. Brown, Prof. G. H. Thomson, and others to whom reference is given at the end of this paper, and whose results are utilised in the sequel without further acknowledgement.

Probably the most accessible work on the subject is the "Introduction to the Study of Statistics," by G. U. Yule, Chas. Griffin & Coy., London, 1912, and his notation is followed herein.

Simple Correlation.

The correlation coefficient, always denoted by the letter "r," may be considered as a measure of the proportion of factors of causation, which underlie any two series of observations to be compared, which are common to both. Thus if the right and left femurs of a large number of skeletons be measured the correlation coefficient is found to be 0.96, which may be taken to mean that of the hundreds of minute causes which determine the absolute length of each limb about 96% are common to both right and

left sides. If the observations are absolutely independent the correlation coefficient will be in the neighbourhood of 0.0 and the extreme limits of +1 and -1 would imply complete direct and inverse dependency respectively.

A positive result will be found in such cases as the fineness of crushing compared with extraction results, where increase in fineness corresponds with increase in extraction, whereas if the total residue values be substituted for the extraction results a negative coefficient of correlation would be expected because an increase of fineness of crushing would correspond with a decrease in total residue values. It is obvious, therefore, that the sign of the correlation coefficient only shows which way the connection works, and it is the absolute value which shows the closeness of the connection. A very small result has very little significance unless the number of observations is very large and is not usually relied upon to show a real connection unless it is at least three times the "Probable error" as subsequently defined.

The following notation is employed in ascertaining the correlation coefficient:—

- X is actual measurement of each item in the one array.
- Y is actual measurement of each item in the other array.
- x is the difference between the mean of the array and each item of X.
- y is the difference between the mean of the array and each item of Y.
- N is the number of observations of X and Y.
- p is the mean product of the associated differences, x and y, and is therefore equal to $\sum xy/N$, that is to say the sum of every xy product divided by the number of observations.
- r is the Correlation coefficient.
- σx is the Standard deviation of the X array.
- σy is the Standard deviation of the Y array.
- b_1, b_2 , are coefficients of regression.

The Standard deviations referred to above are measures of the fluctuations observed and indicate the variability of the subjects considered. The squares of each x (or y) difference are added together, divided by N, and the square root of the result is then the Standard deviation, which is thus shown to be the square root of mean square of the deviations observed. (The average deviation, regardless of sign, though more easily obtained, is not so amenable to manipulation

Month.	% sorted.	Duty.	+ x	- x	+ y	- y	x ²	y ²	+ xy	- xy
1917.										
May...	7.47	3.723		4.18		.049	17.471	.0024	0.205	
June	5.98	3.805		5.67	.033		32.150	.0011		0.187
July	6.33	3.623		5.32		.149	28.110	.0222	0.793	
August	5.80	3.590		5.85		.182	34.222	.0331	1.071	
September	7.51	3.676		4.14		.096	17.140	.0092	0.397	
October	10.23	3.675		1.42		.097	2.016	.0094	0.138	
November	10.24	3.751		1.41		.021	1.988	.0004	0.030	
December	7.96	3.918		3.69	.146		13.615	.0213		0.539
1918.										
January	12.07	3.814	0.42		.042		0.176	.0018	0.017	
February	11.19	3.890		0.46	.118		0.212	.0139		0.054
March	12.36	3.704	0.71			.068	0.504	.0046		0.048
April	12.16	3.768	0.51			.004	0.260	.0030		0.002
May	10.16	4.319		1.49	.547		2.220	.2992		0.815
June	12.28	3.818	0.63		.046		0.021	.0021	0.029	
July	9.09	3.825		2.56	.053		6.554	.0028		0.136
August	9.06	3.825		1.99	.053		3.960	.0028		0.106
September	11.47	3.700		0.18		.072	0.032	.0052	0.013	
October	6.70	3.516		4.95		.256	24.501	.0655	1.267	
November	7.63	3.702		4.02		.070	16.160	.0049	0.281	
December	5.90	3.730		5.75		.042	33.061	.0018	0.241	
1919.										
January	6.69	3.462		4.96		.310	24.600	.0961	1.537	
February	10.64	3.617		1.01		.155	1.020	.0210	0.157	
March	11.15	3.512		0.50		.260	0.250	.0676	0.130	
April	6.72	3.612		4.93		.160	24.303	.0256	0.789	
May	7.97	3.480		3.68		.292	13.542	.0852	1.074	
June	8.78	3.656		2.87		.116	8.238	.0135	0.333	
July	11.57	3.700		0.08		.072	0.006	.0052	0.006	
August	12.30	3.815	0.65		.043		0.022	.0018	0.328	
September	13.30	3.731	1.65			.041	2.722	.0017		0.068
October	14.88	3.750	3.23			.022	10.433	.0095		0.071
November	12.65	3.952	1.00		.180		1.000	.0324	0.180	
December	9.67	3.834		1.98	.062		3.920	.0038		0.123
1920.										
January	11.29	3.693		0.36		.109	0.130	.0119	6.039	
February	15.45	3.602	3.80			.080	14.440	.0064		0.304
March	13.36	3.729	1.71			.043	2.924	.0018		0.074
April	13.77	3.961	2.12			.111	4.494	.0123		0.235
May	17.00	3.891	5.35		.119		28.620	.0142	0.637	
June	14.42	3.897	2.77		.125		7.673	.0156	0.316	
July	14.33	3.857	2.68		.085		7.182	.0072	0.228	
August	18.14	3.700	6.49			.072	42.121	.0052		0.467
September	16.15	3.972	4.50		.200		20.250	.0400	0.900	
October	15.12	3.973	3.47		.201		12.040	.0404	0.697	
November	16.07	3.968	4.42		.196		19.535	.0384	0.866	
December	17.00	3.959	5.35		.184					

and has other disadvantages for our present purposes.)

The coefficients of regression (a rather unsuitable term inherited from Galton) are the deviations of x (and vice versa) corresponding on the average with a unit change in the type of y , and their use in enabling equations to be written exhibiting the connection between X and Y will be illustrated subsequently.

The following equations are of great importance and are easily retained in the memory:—

$$r = \frac{p}{\sigma X \sigma Y}$$

$$b_1 = r \frac{\sigma X}{\sigma Y}$$

$$b_2 = r \frac{\sigma Y}{\sigma X}$$

To determine r in accordance with the first equation all that has to be done is to find the mean of the X column and of the Y column, write down the differences with due regard to sign in two more columns, write down the squares of the differences in further two columns, and so ascertain the standard deviations as above; lastly, the products of each pair of x and y are written down in a final column with the signs attached and p may be determined as above.

For the purpose of illustration and to make the method of working perfectly clear the following example is given of the determination of the correlation between percentage of total sorting and duty per Nominal Crushing Unit of Plant:—

The method of working of the above example is as follows:—

For each month of the period to be considered write down in parallel columns the percentage of waste sorted and the corresponding crushing duty in tons of -90 product per Nominal Crushing Unit. The month is chosen as the statistical unit, rather than the week, or the day, owing to the effect of the storage capacity of the mill bins rendering the correspondence too inexact for short periods, and generally in metallurgical calculations this method is to be preferred for various reasons.

Upon totalling up the columns and dividing the results by the number of entries the

arithmetic average, correct to the same number of decimal places as the entries, is ascertained.

Under the headings " x " and " y " the difference between each item and the average is entered, the positive and negative differences being placed in separate columns for ease of addition.

The addition for the positive and negative columns in each case must be nearly the same, and the differences found may be used as a check by comparing with the remainder found when taking out the averages for the first two columns.

Thus 571.02 divided by 49 gives 11.65 with the remainder 0.17, and the same result is obtained by subtracting the sum of negative differences 73.45 from the total of the positive differences 73.62. A correction could be applied to allow for the neglected decimal places in the true average, but it is not necessary in work of this kind.

The next two columns contain the squares of the deviations shown under " x " and " y ." These columns are added up, the sum divided by the number of entries (49) and the square root of the result extracted. This gives the Standard deviations as explained above.

The last column is obtained by multiplying together each corresponding " x " and " y " and writing down the products in two columns in accordance with appropriate sign.

These two columns are added up, the less subtracted from the greater, and the remainder divided by the number of entries gives the product moment with its proper sign.

The correlation coefficient " r " is then obtained in accordance with the formula shown, and in this case equals $+0.4388$, but in order to be sure of its significance it must be compared with its own standard error.

The probable error of r is equal to

$$\frac{1 - r^2}{\sqrt{N}} \times .67 = \pm .078$$

and as r is more than three times its probable error it is highly probable that the result is significant, and it is fairly certain that the more waste is sorted out the more easily is the remainder reduced in the mill; this, of course, may be due to the fact that the waste is harder to crush than the average ore, or possibly that the proportion of the softer shale is greater in the average ore than in the portion sorted out.

Such alternative conclusions are frequently the result of preliminary investigations, but if the necessary data can be secured a further application of the same methods will yield unambiguous results. In this instance if there is any doubt it can be solved by an examination of the waste sorted and by a comparison of the shale in the sorted rock and in the head gear fines.

Coefficients of Regressions.

The coefficients of regression are usually denoted by b_1 , b_2 , etc., where b_1 is the regression of x on y or the deviation in x corresponding with unit change in the type of y , and b_2 is the regression of y on x or deviation in y corresponding on the average with unit change in x . They are determined as follows:—

$$b_1 = r \frac{\sigma_X}{\sigma_Y} \quad b_2 = r \frac{\sigma_Y}{\sigma_X}$$

$$\text{and } x = b_1 y \pm \sigma_X \sqrt{1 - r^2} \quad y = b_2 x \pm \sigma_Y \sqrt{1 - r^2}$$

the terms preceded by the \pm sign indicating the standard error in estimating y from x or vice versa.

Applied to the above example it will be found that

$$b_2 = \frac{43.8 \times .4593}{3.510} = +.019745$$

and $y = .019745x \pm 0.143$. But it is obvious that $y = Y - 3.772$ and $x = X - 11.67$, therefore $Y = +0.0197 X - 0.143 + 3.542$.

That is the N.C.U. Duty equals 3.542 plus percentage of total sorting multiplied by 0.0197, and the odds are very great that the result so obtained will not be out by 0.429 (that is three times the probable error). Consequently an increase in sorting of, say, 10 per cent. would be followed by an increase in N.C.U. Duty of $5\frac{1}{2}$ per cent. of its previous figure. Though the variability of the hardness of the ore is so great as to render this result uncertain for any particular month yet it would be obtained very closely if a sufficiently long period is chosen.

We have now seen how it is possible from suitably chosen sets of figures to obtain averages and standard deviations, correlations, regression coefficients and characteristic equations, and it remains to be shown from selected examples what information may be extracted from such results and to what use they may be put in improving design or running of metallurgical plants.

Averages and Standard Deviations.

In spite of much interested and interesting calculation expended upon attempting to demonstrate the contrary, mathematicians are in agreement upon the fact that the arithmetical average of a series of observations is more probable than any other, and in itself expresses the essence of possibly lengthy statistics with accuracy and brevity. Comparisons of averages obtained as results of similar operations on various mines are, however, frequently deprived of much value not only owing to differences in the known conditions (which might possibly be eliminated by making the necessary allowances), but also owing to numerous but only partly known variations in the character of the ore such as in hardness, mineralogical composition, distribution and dispersion of the gold. More valuable, therefore, are comparisons of average results obtained for successive periods on the same mine, and in some cases it may prove of interest to compare, say, the average extractions over a period of years for each month and plot the results on the same chart with the temperature and rainfall annual variations.

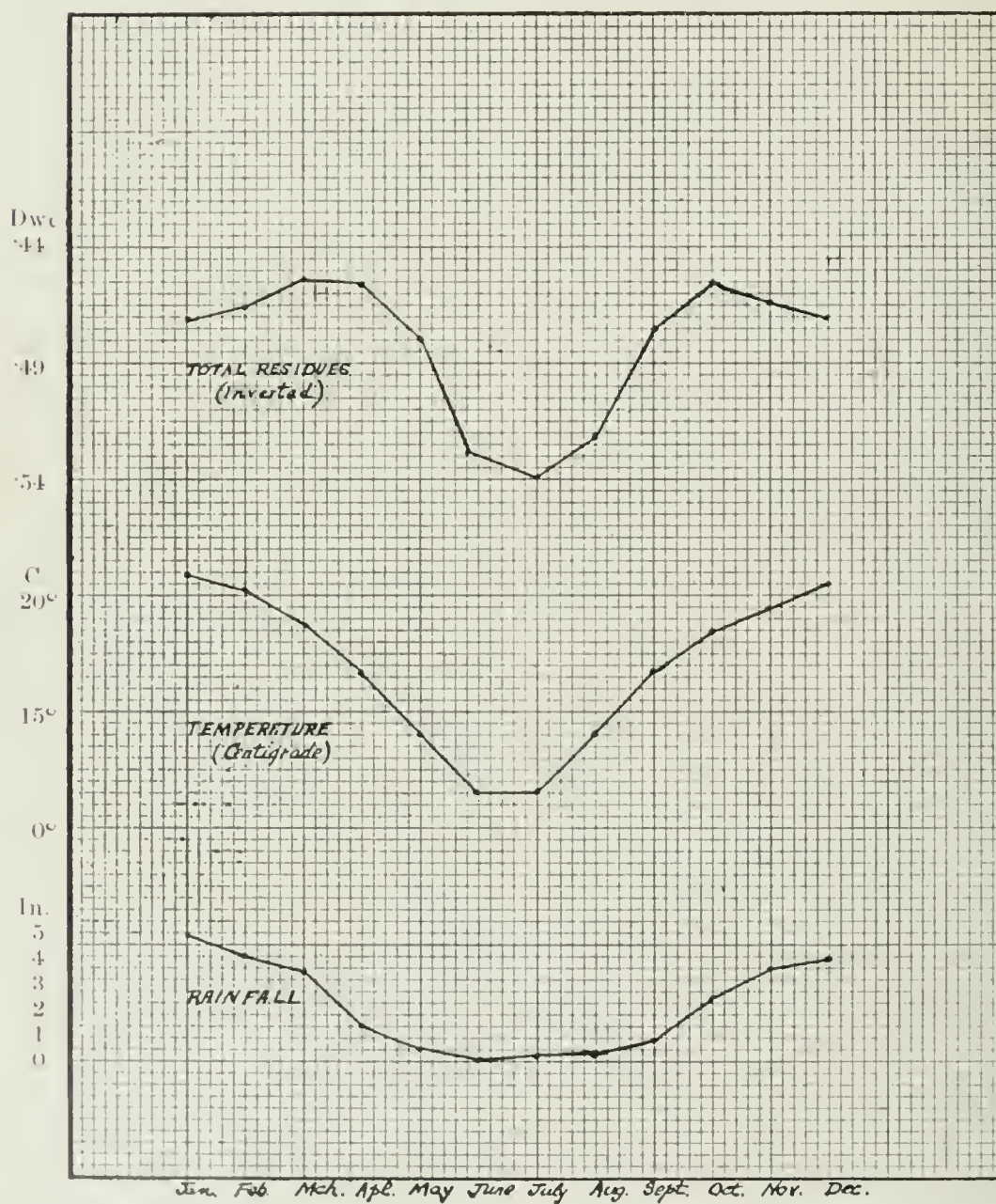
Figure 1 is given in order to illustrate the advantages and suggestiveness of such methods, and throws light upon the discussions which took place years ago as to the connection between temperature and rainfall and the cyanide treatment of banket ore. It will be noticed that there is an obvious suggestion of an optimum temperature for extraction which may be exceeded in the summer months.

Though averages express the truth they do not tell the whole truth, as very wide fluctuations may be entirely ignored. It is on the Far East Rand where, though average values may be high, the percentage of payability of ore developed is low, that greater fluctuations may be expected in all directions than in the Central Rand, and accordingly the standard deviations will illustrate this fact. Probably the simplest and best way of expressing variability in results is shown in the following well-known formula—

$$\text{Variability} = \frac{\text{Standard Deviation}}{\text{Average value}} \times 100$$

The following table shows the variability exhibited by statistics over four years or more on a Far East Rand mine, and their value would certainly be enhanced if similar

FIGURE 1.



results were obtainable for a typical Central Rand mine for comparison.

VARIABILITY OF METALLURGICAL RESULTS.

	%
Screen Values	7.16
Extraction by Amalgamation	7.66
Total Extraction	0.81
Sand Extraction	14.39
Slime Extraction	7.43
Sand Original Value	9.49
Sand Residue Value (Last Drainings)	36.68
Slime Original Value	10.47
Slime Residue Value (Washed)	16.30
Total Residue	13.05
Stamp Duty	3.18
N.C.U. Duty Stamps	7.99
N.C.U. Duty Tubes	6.73
N.C.U. Duty Total	4.22

It will be observed that the variability of the all over extraction is far less than that of the items upon which it depends and that generally Residues are more variable than Extractions.

Another use to which Standard Deviation figures may be put depends upon the fact that differences from the mean values in excess of three times the Standard Deviation are very rarely met with, and that if five times the Standard Deviation is reported a blunder may be looked for.

CORRELATIONS.

In order to give some idea of the range of results to be expected the following list of correlation coefficients is selected from a very much greater number that have been calculated.

They are arranged in order of value, and it will be understood from above that the positive sign signifies that the correspondence is direct while the negative sign shows it to be inverse; where the value is more than three times the standard error some effect is practically certain, where less than the standard error the correlation coefficient indicates the probability that there is no connection between the series involved.

Correlation between

	r	Probable error.
A.V. Pulp and A.V. Slime Original	+0.919	±0.015
A.V. Pulp and A.V. Sand Original	+0.913	±0.016
A.V. Screens and A.V. Pulp	+0.859	±0.025
A.V. Screens and A.V. Slime Original	+0.759	±0.041
A.V. Screens and % Total Extraction	+0.601	±0.148 (1 year)
A.V. Screens and A.V. Sand Original	+0.600	±0.061
KCN % and NaHO % in Slime Sump	+0.530	±0.070
-200 in Slime and Washed Residue	+0.420	±0.079
-90 in Pulp and % of Slime Collected	+0.342	±0.079
Stamp Duty and N.C.U. Duty Stamps	+0.300	±0.087
Screen Aperture and % -90 in Screen Sample	+0.071	±0.095
Stamp Duty and % -90 in Screen Sample	-0.057	±0.096
% Sorted on Surface and Total Extraction	-0.108	±0.083
Ratio Solution to Sand and Last Drainings	-0.589	±0.063
Minutes washed and Last Washings (Slime)	-0.617	±0.059
Minutes washed and Last Washings (Slime) (Sump value deducted)	-0.729	±0.045

A further reference to the significance of some of the above figures will be found later on, but attention may be called to the result that the Percentage of -90 material in Mill Screen Samples appears to be practically unaffected by either the aperture of Screen employed or by the Stamp Duty obtainable, this of course only applies to very coarse crushing as with 1" to 1" Screens.

CHARACTERISTIC EQUATIONS

In order to arouse interest in the method it has been thought preferable to give an

outline of the more noteworthy results obtained for the principal metallurgical operation rather than to take one section and apply the detailed scrutiny required for the complete elucidation of the main factors involved.

Sorting

N.C.U. Duty (total)	3.677	±0.023	*
Total sorting %	0.147		
N.C.U. Duty (total)	3.542	±0.020	*
Surface sorting %	0.143		

In each case r is more than 4 times the standard error, and it seems clear that increased sorting results in improved crushing quality and that the waste sorted out is harder than the ore milled.

Screen Value = $7.664 - 0.048 \times$ Surface sorting % ± 0.838 dwt.

As r is only -0.149 ± 0.073 , that is about twice the probable error, the only absolutely safe conclusion is that surface sorting does not increase the screen value in the way that most discussions on the subject have assumed, and that the only certain method of increasing the value of the ore milled under ordinary working conditions, where tonnage has to be found somehow, is to reduce the stoping widths as ascertained by exact and independent measurements.

Crushing.

Stamp Duty = $17.093 - 2.148 \times$ Average aperture of Screens ± 0.470 .

This is given as an instance of the care that must be exercised in drawing deductions from results obtained. As $r = -0.261 \pm 0.089$ a significant connection is fairly probable, but it is obvious that the conclusion that increasing the screen diameter decreases the Stamp duty cannot be correct. The explanation lies in the fact that in order to maintain a constant tonnage, suitable to other plant conditions, the adjustment is done by changing the screens when the rock varies in hardness, if the crushers have worn a little too coarse or any other factor has changed. Experience can usually decide when two things vary simultaneously which represents the cause and which the effect, but if there is any doubt further statistics can usually settle the matter.

N.C.U. Duty (Stamps) = $0.814 + 0.162 \times$ Stamp Duty ± 0.250 .

As $r = 0.300 \pm 0.087$ it is evident that there is a strong common underlying factor no doubt connected with the hardness and toughness of the ore mined.

Tube Milling.

N.C.U. Duty (Tubes) = $4.130 - 0.150 \times$ Screen aperture ± 0.270 .

As r is only 0.033 ± 0.096 and is thus much less than the probable error the important conclusion can be drawn that the Tube duty is not affected by size of particles fed within the range dealt with from $\frac{3}{8}$ " to 1".

N.C.U. Duty (Tubes) = $1.152 + 0.034 \times$ % of - 90 entering ± 0.255 .

N.C.U. Duty (Tubes) = $4.106 - 0.002 \times$ % of - 90 leaving ± 0.270 .

These equations demonstrate the importance of keeping the tube feed as free as possible from - 90 material, but shew the insignificant effect of the grading leaving the tubes, contrary to the popular impression (previously shared by the author). In this connection variations in the - 200 material must be considered.

Grading Analyses.

% - 90 in Final Pulp = $77.26 + 11.488 \times$ Mill Screen aperture ± 2.075 .

This equation was calculated in order to test the equation given under Crushing, and merely confirms the explanation there given of the apparently anomalous effect of increasing the aperture of the mill Screens. If the Screening were changed independently of ore feed conditions it is obvious that very different figures would result for both equations.

% of ore collected as Slime = $27.20 + 0.426 \times$ % - 90 in final pulp ± 1.64 .

The value of r is 0.363 ± 0.083 , and the result of increasing the percentage of - 90 in final pulp can readily be calculated as to the effect upon proportion to be treated in the Slime Plant. If all the ore is crushed to pass 90 Screen this would only give from 69.8 to 71.4% of ordinary Slime, and this would certainly not be "All Sliming," as sometimes stated in the Financial Press.

Assay Values.

A.V. Pulp (Direct) = $0.738 + 0.823 \times$ A.V. Pulp (Calculated) ± 0.219 .

As r has the high value 0.852 ± 0.026 the obviously close connection is well brought out, but each figure is subject to its own independent causes of variation to a slight extent.

Pulp Value (Direct) = $-0.484 \pm 0.671 \times$ Screen Value ± 0.274 .

Pulp Value (Calc.) = $0.292 + 0.559 \times$ Screen Value ± 0.318 .

The value of r for direct value of pulp sample is 0.859 ± 0.025 against 0.740 ± 0.034 for the calculated value from Assays of Slime and Sand and tonnages of each. Though better samples can probably be taken from the two latter products the variations caused by errors of tonnage estimates cause the direct pulp sample to possess the higher probability.

A.V. Slime Original = $0.918 + 0.555 \times$ A.V. Sand ± 0.361 .

As r is 0.710 ± 0.048 there is a considerable common cause underlying both fluctuations, and this is obviously the variation in Screen value of the ore.

Extractions.

Total Extraction = $99.46\% - 0.004 \times \text{Tons Milled per day} \pm 0.66\%$.

$r = -0.482 \pm 0.074$, and of course the equation applies only when the size of plant is fixed and the tonnage actually treated varies. Supposing a fairly balanced plant gave an extraction of 94.26% when treating 1,300 tons per diem; at 1,400 tons the Extraction would be 93.86 , at 1,500 tons it would be 93.46 , and at 1,600 tons it would be 93.06% , with a fluctuation of a little more than a half per cent. either way. The often mentioned "capacity" of a plant is therefore not a definite figure unless the extraction percentage at the economic limit is also given. Of course the economic limit of extraction is not the same on the Far East Rand as on the Central Rand, and is probably not exactly the same figure even on neighbouring mines.

Total Extraction = $89.19\% - 0.050 \times \% \text{ of } -90 \text{ in Pulp} \pm 0.74\%$.

Here the value of r is only 0.146 ± 0.096 , which indicates that the effect of finer grinding may be masked by variations in the ore in other directions, and in any case is not so great as usually found on the Rand; increasing from 90% of -90 in the final pulp to the so-called "All Sliming," that is to 100% of -90 , can only be expected to increase the extraction by half a per cent. and requires either high value ore or cheap crushing in order to be economical.

Slime Extraction = $91.13\% - 0.201 \times \% \text{ of } -200 \text{ Sand} \pm 0.59\%$.

As $r = 0.505 \pm 0.071$ the effect upon Slime Residue of the presence of >200 Sand is quite certain and the inclusion of 35% of such material in the portion treated as slime by ordinary methods would in accordance with above equation lower the extraction obtainable by 7% . This conclusion is of course liable to an extrapolation error, as it is beyond the usual range, and this would apply even more to the conclusion that the equation for 100% of -200 Sand would show only 74% Extraction, but the deduction that the best place for this material is the Sand Vats appears to be just.

Stores Consumed.

Cyanide lb. per ton = $0.46 - 0.031 \times \% \text{ of Slime Treated} \pm 0.02$.

$r = -0.228 \pm 0.061$, and it is therefore probable that a gain may be made on cyanide

consumption by treating as much as possible of the ore in the Slime Plant.

Temperature and Rainfall.

Mill Extraction = $23.41 + 0.268 \times \text{Degrees Fahrenheit} \pm 2.47\%$.

The correlation coefficient is 0.549 ± 0.067 , and this makes it practically certain that increased temperature is very beneficial to amalgamation extraction. This throws light upon the discussions on this point held years ago in this Society, when, however, the freedom of debate was not circumscribed by adequate statistics. The effect can readily be explained by a consideration of the fact that higher temperature not only reduces the viscosity of water very considerably, thus enabling gold almost fine enough to escape to be retained on the plates or in the final cones, but also reduces surface tension and slightly decreases the specific gravity of the fluid in which all the operations are performed.

The temperatures used in this calculation were kindly supplied from the Johannesburg Observatory and through the courtesy of Mr. Stewart, Government Meteorologist. They are based on the mean between the average maximum and minimum daily temperatures for each month.

Total Residue = $0.692 - 0.0035 \times \text{Degrees Fahrenheit} \pm 0.059 \text{ dwt.}$

Here again the correlation coefficient is -0.342 ± 0.085 , and high enough to render it certain that higher temperature improves extraction, though a reference to figure 1 will show the probability that a limit in this direction is reached at about nineteen degrees centigrade for a monthly average, and the suggestion is that decreased solubility of oxygen and increased chemical action for other competitors than gold begin to take effect more conspicuously than the increased rate of diffusion of sodium cyanide will counterbalance.

By a somewhat different method of calculation a figure called the correlation factor can be calculated in cases of this sort, where a maximum or minimum is involved, and the relation to be developed is not sufficiently nearly linear, but it is usually sufficient to use the present method if a diagram of the observations is plotted in order to avoid serious errors of interpretation.

Percentage of -200 in Slime = $9.8 - 0.056 \times \text{Degrees Fahr} \pm 1.7\%$.

The correlation coefficient is only a little more than twice the probable error, but it is clearly probable that the part of the +200 material which might just escape to the Slime Plant in cold weather is allowed to settle in the sand separators when the temperature is higher for the same reasons as are operative in the case of amalgamation as given above. The deduction must be drawn that the old-fashioned method of intermingling the condensor water with the mill circuit has possibly been dropped without due consideration of all the factors involved.

It has been found that there is strong correlation between the rainfall and monthly temperatures, due to the fact that our rainfall is seasonal and in the summer months; and though a considerable correlation can be demonstrated between the rainfall and mill extractions it is not probable that any direct action is considerable.

MULTIPLE CORRELATION.

So far we have dealt with simple correlation, which only deals with the variation caused by one factor when all the others are varying at the same time and our equations involve only two unknowns. By a somewhat lengthy manipulation of the correlation coefficients for every pair of up to 4 factors it is possible to deduce equations in which the coefficient of each factor determines its effect, when all the other factors are held constant and two equations are given below to show what sort of result may be obtained in this way.

It is not proposed, however, to show how to calculate such equations unless the discussion shows that it is strongly demanded.

$$\text{Screen Value} = 6.874 - 0.089 \times \% \text{ Sorted on Surface} + 0.092 \times \% \text{ Total Sorting} \pm 0.816.$$

This equation certainly provides cold comfort for the advocates of increased sorting on the surface, but the correlation involved is only 0.276, which shows that other more important factors such as stoping widths and reef value variations are in operation.

$$\text{Total Extraction} = 90.36 - 0.0049X + 0.696Y + 0.0552Z \pm 0.057\%$$

Where X = Tons milled per diem

Y = Screen Value

Z = % of -90 in Pulp.

This shows the increased effect of finer grinding observed when the tonnage is held constant and with unvarying Screen Value, but does not materially affect the results pre-

viously arrived at by simple correlation methods, but only increases their accuracy and certainty. The effect is very much the same as with ordinary chemical, physical, or metallurgical experiments, where all the factors but one are kept constant and the effects of varying this one factor observed. The twofold advantage is, however, secured of using the actual working scale for the experiments and collecting the independent effects of four variables at once. It is even possible to determine any number of factors in this way, but the arithmetical work, lengthy with four factors becomes practically prohibitive if more are attempted.

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Various articles will be found in the Philosophical Magazine, and in Philosophical Transactions, by Karl Pearson, F. Y. Edgeworth, E. C. Snow, L. Isserles, and others dealing with particular branches of this subject, and the last edition of the Encyclopedia Britannica may be consulted with advantage.

DISTRIBUTION OF GOLD IN BANKET ORE CLASSIFIED PRODUCTS WITH REFERENCE TO MILLING AND CYANIDING OPERATIONS.

By F. WARTENWEILER.

DISCUSSION.

Mr. H. R. Adam. With regard to the question of the association of the gold and the pyrite in banket ore it is a little unfortunate that Mr. Wartenweiler added panings of the flotation tailing to the flotation concentrate; otherwise the flotation method distinctly overcomes the "forced" association suggested by Mr. White. The flotation con-

concentrate must consist of clean pyrite along with a greater or lesser proportion of "mixed" particles, but silicious particles having no attached pyrite would not float to any extent even if all the gold in the sample were distributed amongst them. Further it is difficult to conceive, with such low-grade material as was treated, of anything but a negligible number of gold particles unattached to either pyrite or silicious particles.

The figures in the first two tables are very clear indications of the association of the gold with the pyrite. A greater percentage recovery of gold was naturally obtained by prolonged flotation since the concentrate would then contain most of the "mixed" grains as well as the clean pyrite, but the actual gold value of the clean pyrite is considerably higher than when a greater proportion of silica is present, *e.g.* :—

Table I (prolonged flotation)—

Value of concentrates—

22 dwts. ton and 36.2 dwts. ton.

Table II. (same samples, clean pyrite)—

Value of concentrates—

36.2 dwts. ton and 55.1 dwts. ton.

i.e., the cleaner the pyrite the higher the gold value.

The value of Mr. Wartenweiler's figures, as far as this particular problem is concerned, is greater than that of those quoted by Dr. Caldercott since the "gravity" tailing contained as much as 82.5% pyrite while the flotation figures were as low as 16% and 0.8%.

Notices and Abstracts of Articles and Papers.

CHEMISTRY

FUEL ECONOMY RECOMMENDATIONS IN ENGLAND—The Fuel Economy Committee of the Federation of British Industries states that the efficient working of a boiler plant may be considered as consisting: (1) In utilizing the heat of the fuel as completely as possible in the boiler furnace, and delivering it to the heating surfaces in the form best suited for heat transmission; (2) in securing the best possible transmission of this heat through the plates or tubes of the boiler for the generation of steam; (3) in avoiding as far as possible losses of heat from the boiler plant; and (4) in using steam as economically as possible for the requirements of the boiler plant itself, in order to leave the maximum proportion available for external purposes. The recommendations of this committee are: (1) Avoid unnecessary wastage of fuel in the boiler by cleaning the fires carefully and by providing suitable grates; (2) avoid the

production of unnecessary smoke or incompletely burnt gases by regular and frequent firing of coal in small quantities, and by keeping a proper depth of fire. Open the air checks in the furnace doors only after firing, at other times keeping the checks closed; (3) regulate the draught by the damper to burn the coal with the minimum excess of air. Try to obtain 12% CO_2 in the furnace gases, and, if necessary, reduce the grate area to secure this result; (4) keep the grate covered, the fires level and free from holes. Use the rake when necessary; (5) carefully examine the setting and stop all in-leakages of air; (6) keep the heating surfaces free from soot and flue dust; (7) keep the internal surfaces free from scale; (8) do not force the boilers unnecessarily; (9) examine flues and baffles carefully. Repair where necessary to avoid by-passing; (10) efficiently lag the boilers and steam pipes, including flanges; (11) do not blow down the boilers unnecessarily; (12) keep the boilers filled to the working level by a continuous and steady feed; (13) avoid leakages of steam from boiler fittings, drains, etc.; (14) if steam is used in pumps or auxiliaries, use the exhaust for pre-heating the water; (15) if steam jet blowers are used, keep the jets in good condition by renewal as necessary, and regulate the pressure on the jets to the minimum necessary for the load; (16) if economisers are provided, record the temperatures of water entering and leaving; (17) make periodical measurements of CO_2 in, and temperature of, flue gases leaving the boiler under average conditions, to estimate the approximate boiler efficiency.—*Ind. Engineering*, pages 116-7, September 10, 1921. (J.A.W.)

QUANTITATIVE PRECIPITATION OF GOLD BY MEANS OF THE ELECTRIC CURRENT. W. D. Treadwell [*Helvetica Chimica Acta*, 1921, iv., 361-367] states that metallic gold may be deposited quantitatively from its solution as a chloride by means of the electric current, provided the solution contains ammonium acetate plus either hydrochloric or sulphuric acid. Using this electrolyte and the proper voltage gold may be separated from copper, palladium and platinum.—W. D. TREADWELL, *Journal Franklin Institute*, Vol. 192, No. 3, page 290, September 1921. (J.A.W.)

VOLATILISATION OF REFRACTORY SUBSTANCES.

A very interesting account of an extensive series of experiments on the "Relative Volatility of Refractory Materials" was communicated to the American Electrochemical Society by Mr. W. Roy Mott, of the National Carbon Company, Cleveland, Ohio, in 1918, and a further communication by Mr. Mott on the subject appeared in the latest thirty-seventh volume of the Transactions of that Society under the title "Arc Images in Chemical Analysis." Mr. Mott drills a hole 3/8th inches in diameter and depth into the lower positive arc carbon, ordinary high-grade enclosed arc carbon 4in. in diameter not containing more than 0.1% of ash—places about 0.5 gramme of the substance into the carbon cup and starts the 25-ampere arc at 50 volts on a 110-volt direct-current circuit. The material is then

volatilised; the most refractory residue remains in the cup, the vapours condense on the lower and upper carbons in beads, mirrors or rings, partly of exceedingly fine particles, the least volatile close to the crater, and conclusions as to the volatility are drawn by measuring the distances of the deposits from the carbon tips or from distinct rings of iron, etc., first deposited, and from other features. The measurements are made on pin-hole images of the arc, and time, brightness, structure of the deposits and colour phenomena are observed. The experiments are modified in various ways. A pure substance is first volatilised; it is then mixed with various other substances in different proportions for new measurements. Or a negative carbon is coated, say, with copper, by arc distillation, and the coated portion is then reheated in the arc, for two minutes; a certain measured portion of the copper will be revolatilised. Or the arc is interrupted while revolatilisation is proceeding; the hot carbons will then continue to "smoke" for measured periods of seconds or minutes; this method is applicable only to substances boiling below $2,000^{\circ}\text{C}$. In these ways it is found that metals, not forming carbides, will distil in the order cadmium, zinc, thallium, lead-bismuth (these two metals distilling together), antimony, silver, tin-copper, gold; the iron metals, Ni, Fe, Co, Cr (except Mn), are also superposed and cannot be separated by these methods. Most of the metals are deposited as oxides. In estimating the boiling points Mott assumes—from the observations of his own and of others—that the temperature of the carbon crater is $3,700^{\circ}\text{C}$., and that tungsten boils at $6,000^{\circ}\text{C}$., iron saturated with carbon (like all the metals) at $3,500^{\circ}$, silica at $3,500^{\circ}$, aluminium oxide at $3,700^{\circ}$, chromium carbide at $3,800^{\circ}$, platinum at $4,050^{\circ}$, zirconium oxide at $4,300^{\circ}$, thorium carbide at $5,500^{\circ}$, and tantalum or its carbide at $5,500^{\circ}$; in the case of tungsten a fusing carbide seems to be formed, but the carbon boils away. Materials boiling below $2,500^{\circ}\text{C}$. generally give long, steady arcs, more refractory materials give unsteady arcs, partly owing to variable cratering. Hydrogen compounds, such as water, ammonium salts, organic compounds, volatilise readily and yield short unsteady arcs; fluorine can be identified in the presence of calcium by the green band in its arc spectrum; iodine is recognised by its odour and its purple vapours; boron and phosphorus colour the flame tip green; boron also gives a green flame core with a yellow-red shell; metals increase the arc length; in the uranium arc flame blue, green and red colour zones appear. There are many other characteristics which enable Mott to detect 0.02 milligramme of gold and tungsten, and 0.1 milligramme of the rare earths by this rapid arc analysis. Mott has in fact worked out a system of analysis by arc images covering a large domain of inorganic chemistry, which looks promising for routine analysis as well as for research. (*Engineering; Ind. Aus. (C.J.G.)*)

DETECTION OF CARBON MONOXIDE.—The detection of this substance in air and other gases, when present in quite small proportion, has been a problem of importance and of some difficulty. It is a very poisonous gas, having a

special cumulative effect, by which the continued inhalation of very small amounts will ultimately produce serious conditions. C. R. Hoover, of Wesleyan University, gives an account in the *Jour. Ind. Eng. Chem.* (1921, XIII., 770) of the use of a new reagent, Hoolamite, which consists of fuming sulphuric acid and iodine pentoxide, mixed with an inert supporting material. This reagent was the subject of a patent by Messrs. A. B. Lamb and C. R. Hoover, from which presumably the uncouth name is derived. The inert material used is pumice. The reaction is the conversion of the reagent into a green mass, the depth of colour being mainly proportional to the concentration of the carbon monoxide in the gas tested. Two portable devices are described by which approximate quantitative measurement made. It has been found that one of these devices is sufficiently sensitive to detect in a few seconds carbon monoxide in proportions believed to be harmless to human beings or the larger animals. The use of the instruments is not difficult, and it is hoped that very soon further improvements will be made in the preparation of the reagent and the operation of the apparatus. Carbon monoxide is, however, not the only gas which reacts, but all other gases, so far tested, that stimulate it, are absorbed by dry animal charcoal, which does not appreciably absorb carbon monoxide. Some common gases are entirely without action. Hoolamite is a corrosive, deliquescent material, and must be kept in closed vessels. Its activity increases for a few days after preparation, then becomes stationary and remains so for a long while. It is usually kept in small sealed glass tubes.—*Journal Franklin Institute*, Vol. 92, No. 4, page 496, October, 1921. (J.A.W.)

FUEL ANALYSIS.—The Fuel Research Board of the Imperial Resources Bureau have under consideration the standardising of methods for the sampling and analysis of coal, and they hope shortly to publish their recommendations on this subject.

A few preliminary observations on the subject of fuel analysis are, however, given in the Bureau's work on "Coal, Coke and By-products," in which it is explained that proximate analysis is the percentage composition of the coal in terms of fixed carbon, volatile matter, ash and moisture, and ultimate analysis the percentage composition in terms of carbon, hydrogen, nitrogen, oxygen, sulphur and ash.

Proximate Analysis.

Moisture.—When a sample of freshly-won coal is left exposed to the air, it loses by evaporation part of the water which it contains, but retains another part. The former is described as "air-drying loss," and the latter as "hygroscopic water." Practically the whole of the "hygroscopic water" can be driven off by desiccation at a temperature slightly above the boiling-point of water, say, at 105°C . Water driven off above this temperature is regarded as "combined water," and is considered as part of the coal substance. There is no exact line of demarcation between the "air-drying loss" and the residual moisture in air-dried coal, as the hygroscopicity of coal increases with increasing relative humidity of the air, and is also influenced by its fineness.

Volatile Matter and Fixed Carbon.*—The volatile matter and fixed carbon represent approximately the relative proportions of gases and solid combustible matter that are obtained from coal by heating it in a closed vessel. The volatile matter consists chiefly of compounds of carbon, oxygen, hydrogen and water-vapour. Except in the case of a "coke assay," the volatile matter does not include the water that can be removed from the coal by heating it at 105° C.

The amount and composition of the volatile matter that may be obtained from a given coal vary with the temperature and the method of heating. The influence of these factors is responsible for the variations that frequently obtain in the analytical determination of volatile matter. Failure to observe the same method of heating in different laboratories may result in deviations of 2%, or 3%, in the respective amounts of volatile matter and fixed carbon in reports made on the same sample of coal. A difference in the estimation of the relative proportion of volatile matter and fixed carbon in a given sample of coal becomes more pronounced in the British "fuel ratio," which gives the ratio of the fixed carbon to the volatile matter. This will be seen by the following example, where a difference of 3% in the estimation of the volatile matters makes a difference of 17% in the fuel ratio:—

	Per cent.	Per cent.
Fixed carbon	77.19	74.19
Volatile matter	18.53	21.53
Ash	3.04	3.04
Moisture	1.24	1.24
	100.00	100.00
Fuel ratio	4.17	3.15

The best temperature for the determination of volatile matter appears to be 950° to 1,000° C. At the present, the method of determination is arbitrary, and therefore results are comparable only when the temperature and rate of heating are the same.

Sulphur. In an ordinary proximate analysis of a sample of coal the sulphur, which becomes distributed among the fixed carbon, the volatile matter and the ash, is not determined. If the ash contains no lime or alkali oxides (when a large proportion of the sulphur may be retained in the ash as calcium sulphate) all the sulphur is distributed between the volatile matter and the fixed carbon; approximately half of the sulphur being retained by the fixed carbon, and the remainder escaping with the volatile matter. If the relative distribution of the sulphur between the fixed carbon and the volatile matter is required, a determination of the sulphur in the "fixed carbon" can be made. The difference between that result and the total sulphur in the coal giving the quantity of sulphur in the volatile matter. The proximate "moisture and ash-free" analysis of a coal must not be confounded with the "coke assay" of the same coal, which consists simply in the determination of (a) non-volatile matter (coke), and (b) volatile matter. In this case the ash

is included in (a), and the moisture is included in (b).

Ultimate Analysis.

An ultimate analysis is not subject to the arbitrary conditions that characterise a proximate analysis. The percentage of oxygen is obtained by difference—that is, by subtracting the sum of the percentages of the other constituents from 100; consequently the oxygen percentage bears all the errors of the other determinations. It must be remembered that (when it is not stated separately) the moisture contained in the sample which is analysed is included, in an ultimate analysis, in the determination of hydrogen and oxygen.

In considering an analysis—whether proximate or ultimate—of a sample of coal for the purpose of comparison with other analyses, it is important to note whether the analysis is given on a sample (1) "as received"—that is, undried and containing extraneous moisture; (2) "air-dried"—that is, containing inherent moisture only; (3) "moisture free"—that is, when the percentages are calculated upon the total constituents of the coal, exclusive of all moisture; (4) "moisture and ash-free"—that is, when the percentages are calculated upon the total constituents, exclusive of moisture and ash.

The following table gives the several statements of analyses of the same coal according to the method adopted.

Analyses of the same coal, differently stated:

	As Received	"Air-dried"	"Moisture free"	"Moisture and ash-free"	As received "Coke Assay."
	%	%	%	%	%
<i>Prev. Analyses</i>					
Moisture					
Lost on air drying	5.60				Included in volatile matter
Inherent Moisture	10.70	16.6	11.4		Included in coke
Ash		7.6	8.1	9.1	
Volatile Matter		12.1	34.1	38.5	48.7
Fixed Carbon		43.7	49.1	52.4	51.3 (coke)
	100.0	100.0	100.0	100.0	100.0
<i>Ultimate Analyses</i>					
Carbon		56.3	50.8	67.5	74.4
Hydrogen		5.6	5.2	3.5	4.9
Oxygen		28.9	25.3	17.0	18.7
Nitrogen		1.2	1.2	1.1	1.5
Sulphur		0.1	0.1	0.5	0.5
Ash		7.6	8.1	9.1	
	100.0	100.0	100.0	100.0	100.0
<i>Caloric Value</i>					
(B.Th.U.)	9,199	10,128	11,596	12,128	
Fuel Ratio (B.Th.U.)	1.36	1.36	1.36	1.36	

Calorific Value.

The calorific value or power of a fuel is the amount of heat evolved by the complete combustion of unit weight of the fuel, and is measured by the number of units of weight of water, the temperature of which it is capable of raising one degree. It is usually expressed either as calories or as British thermal units (B.Th.U.) and the relationship of these is that which exists between the Centigrade and Fahrenheit degrees of temperature. Hence, to convert calories into B.Th.U., multiply by 1.8.

As will be observed by reference to the table given above, the statement of the calorific value

* The terms "volatile matter" and "fixed carbon" do not represent definite compounds that exist in the coal before heating.

of a sample of fuel will differ according as the sample referred to is considered (1) "as received"; (2) "air-dried"; (3) "moisture-free"; (4) "ash and moisture-free."

Evaporative Power.

The calorific value of a fuel is sometimes expressed by the number of pounds of boiling water (100° C.) which would be evaporated or converted into steam at (100° C.) by the heat from the complete combustion of 1lb. of the fuel. This quantity can be deduced from the calorific value of the fuel expressed in calories by dividing the latter by 537 (the "latent heat" of steam expressed in "calories"), or from the value expressed in British thermal units, by expressed in B.th.u.).

Fuel Ratio.

The British "fuel ratio" is the number which expresses the proportion which the "fixed carbon" bears to the "volatile matter" in proximate analyses.

The American "fuel ratio" is the number which expresses the proportion which the total of the "fixed carbon," moisture and sulphur bears to the volatile matter.

Sampling.

The value of an analysis of a fuel depends primarily on the representative character of the sample analysed, and failure to secure a representative sample, due to any cause, may result in errors far larger than any of the chemical errors. The following are among the causes which may lead to deceptive results*:

(1) Failure to secure a representative sample due to the faulty method of sampling of a car of coal by merely taking several lumps, or shovelfuls, from the top of the car.

(2) Difficulty in securing a representative sample due to the occurrence and the irregular distribution of materials of different composition, as the irregular distribution of pyrites.

(3) Alterations or changes in the sample during handling or before it is analysed, as changes due to gain or loss of moisture, or changes due to oxidation.—*South African Engineering*, September, 1921, page 185. From "Coal, Coke and By-Products," published by the Imperial Mineral Resources Bureau. (A.K.)

METALLURGY.

DEVELOPMENT OF A COPPER PRECIPITATING APPARATUS.—In precipitating copper from leaching solutions in connection with the SO_2 process and from acid mine water the common precipitating equipment in the past has been a long launder with a false bottom of grating on which the iron precipitant has been placed. This type is difficult and laborious to clean and does not usually permit a high precipitating efficiency of copper, and usually involves a high iron consumption.

After much experimentation the author has devised an improved apparatus designed on the principle of using a circular wooden vat having a false bottom of grating. The solution to be precipitated is entered through a centre box communicating to the space below the false bottom; it then flows upward through the grating and the masses of iron with which the vat is filled above the grating and dis-

charges into a peripheral launder. A Dorr thickener mechanism is placed in the tank, the centre shaft passing down the central feed box and the plow arms working beneath the false bottom. By raising and lowering these arms and by the arrangement of various speeds the mechanism may be worked periodically to give a violent stirring effect to the solution in the vat, thus dislodging the loosely formed copper precipitate from the scrap iron and by lowering the arms to a position close to the vat bottom and operating at a slow speed, the copper precipitate which has dropped through the grating may be mechanically discharged through the bottom.

This precipitate is usually collected and dried before shipment to a smelter. Precipitation has been as high as 97.7% on a solution carrying 1.60% copper.

Experiments have been carried out with various forms of iron for precipitating the copper. The following table of results shows the ratio of iron consumed, percentage of copper in the precipitate, and the ratio of coarse to fine precipitate with a solution of a composition of: Cu, 2.4%; FeSO_4 , 2.8%; $\text{Fe}(\text{SO}_4)_3$, 0.3%; Al_2O_3 , 1.6%.

Precipitant	Ratio of Iron consumed to Copper precipitated	Ratio of Coarse Copper to fine	Precipitate % Cu
Pig iron	1.35:1	98 : 2	94.4
Wrought iron ...	1.6 : 1	94 : 6	87.2
Cast iron	1.65:1	93.5:6	86.8
Steel shavings ...	2.10:1	86.5:13	72.7
Cast steel	1.75:1	94.1:6	80.1
Tin Cans	2.35:1	81 : 19	66.9

—JOSEPH IRVING, JR., *Mining and Scientific Press*, October 15, 1921. (F.W.)

AN IMPROVED TYPE OF FILTER PRESS.—The author first deals with different types of filters used in large mechanical filtering operations. For material of a free filtering nature containing no colloids a form of rotary vacuum filter with continuous operation is recommended in order to save cost of dumping. When high pressures are desirable and the solid is not to be recovered in a dry form the rotary pressure filter is suggested. When a solid cake is desired and for materials difficult to filter, the plate and frame type of filter press is recommended. Although requiring labour to discharge, it has certain advantages such as simplicity, ruggedness and compactness. The washing of the cake is also under better control and more positive. The author has given this old type of press considerable study, and has designed certain improvements, which he has embodied into a new filter press called the Duplex.

He has found that the usual plate surfaces consisting of corrugations or a series of truncated pyramid projections cast on the plate do not offer the best means of outlet for the filtrate, as the cloth is pressed on to the pyramids and into the depressions, thus seriously retarding the flow and the filtering area, especially where high pressures are employed. He supports the cloth on a double crimped wire screen instead, overcoming those objectionable features. The centrifugal pump is preferred for press filtering as its volume adjusts itself to the increasing pressure, and cannot go to

* "Coal," by E. E. Somermeier; 1912; p. 57

excessive pressures if properly installed. It is also free from pulsations. Other improvements in design include large inlet ports in each of the upper corners of the frame, allowing rapid filling and quick venting of displaced air in starting. Two separate outlet channels for the filtrate are provided at the bottom of the plates. By means of an ingeniously arranged sight glass and stop-cock the filtrate passes from the plate through the glass and back into the channel of the plate. Each side of a plate may therefore be observed, and if a leak develops, shut off without interfering with the rest of the press or the other side of the plate.—CHARLES D. BURCHENAL, *Chemical and Metallurgical Engineering*, page 476. September 7, 1921. (F.W.)

DIFFERENTIAL FLOTATION OF LEAD-ZINC ORES.—On the basis of experimental work done by the United States Bureau of Mines, in co-operation with the University of Idaho, the Bureau of Mines and Geology of the latter State, and certain mining companies of the Coeur d'Alene region, differential flotation separations of lead and zinc sulphides in lead zinc ores have been proved to justify the following conclusions:—

- (a) Complete separation of the lead and zinc sulphides by differential flotation is not possible owing to the intimate association of the minerals.
- (b) Fine grinding is essential in order to liberate most of the sulphide minerals and to permit separation.
- (c) A better recovery is, however, possible with an ore that has been crushed dry.
- (d) A pulp density of between two and one-half and three and one-half parts to one part solids seems to give the best results.
- (e) Each ore seems to require a somewhat different flotative mixture, and the effect of a certain oil or chemical on one ore may be different on some other similar ore.
- (f) A better separation of the sulphide minerals was obtained by differential flotation than has been obtained by existing methods.
- (g) A better differential selection of the lead from the zinc sulphide is effected with an alkaline or neutral pulp than with an acid pulp.
- (h) Soda ash, sodium hydroxide, sodium silicate, water glass, salt, lime, coal tar, creosote, alcohol, gasoline and charcoal seem to assist in the selective separation and recovery of lead sulphide in the presence of zinc and iron sulphides, the effectiveness of which, however, may be modified by the gangue constituents present in the ore.
- (i) Copper sulphate or some other copper compound, such as copper carbonate, when added to a pulp containing soda ash after the lead concentrate has been removed, seems to give good results in floating the zinc mineral with some of the ore.
- (j) The Bradford 80 process seems to be applicable to the treatment of some of the ores.
- (k) Differential flotation should be applicable to some of the ore, with good grade products of lead and zinc and good recovery of both minerals, especially by a roughing and cleaning system.

Of general results obtained by differential flotation, separations of lead and zinc sulphides in lead-zinc ores, the following have been verified by assays, giving lead products of from 50% to 60% Pb. and 5% to 8% Zn; and zinc products containing 40% Zn. and 4% to 6% Pb.
About 75% to 80% of the zinc products are recovered. These do not include cleaning tests.—(*Commun. Inst. A.M.M.*, No. 174, 1921, p. 27; *Ind. Aus. and Min. Stand.*, September 28, 1921, p. 591. (C.J.G.)

MINING.

PUMP COLUMN CLEANING AT THE ROBINSON GOLD MINE.—The following experience in pump column cleaning at the Robinson Gold Mining Co., by Mr. Blyth, was given at a recent meeting of the South African Institution of Engineers, with a view of helping those who should experience similar difficulties.

With regard to the pumping plant, it should be stated that the columns run through an incline shaft, the average angle of which is 34³ degrees. It consists of 10in. piping, wood lined to a diameter of 9in. from collar of shaft to fourteenth level, which is situated at a vertical depth of 1,040 feet (1,739 feet incline). From the fourteenth to the seventeenth levels, the depth of which is 352 vertical (720 feet incline), 7in. piping is used, wood lined to a diameter of 6in.

Tenth Level.—One single-acting triplex plunger pump; maker unknown; with capacity of about 7,000 gallons per hour.

Fourteenth Level.—One Gould's single-acting triplex plunger pump, with a capacity of 8,000 gallons per hour.

Seventeenth Level.—One Gould's horizontal triplex plunger pump, double-acting, with a capacity of 10,000 gallons per hour.

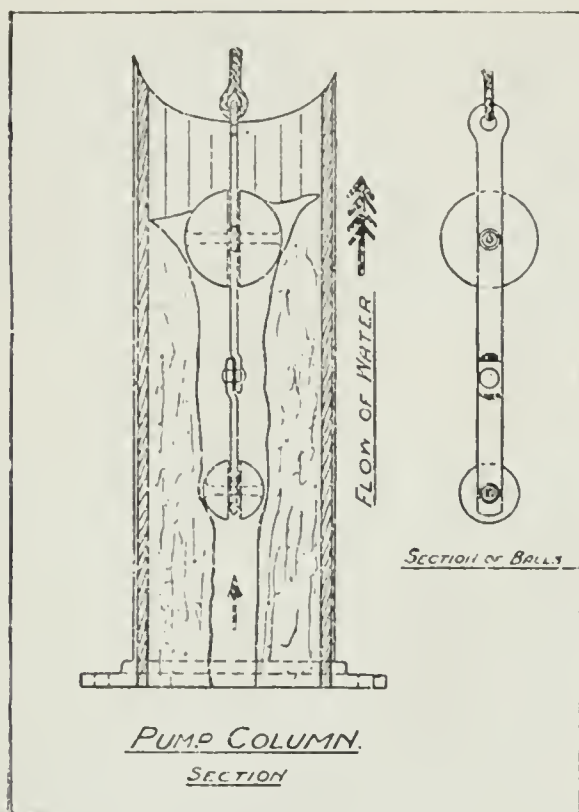
The above pumps are motor driven, the tenth and fourteenth levels being on a 500-volt circuit, and the seventeenth level on the 2,000-volt circuit.

About January, 1920, the above pump column was in a very bad state, being heavily furred. The aperture at places was as small as 3¹/₄in.

These conditions were, of course, the cause of excessive pressure, and consequently wear and tear on the pumps, particularly at the seventeenth level, where the pressure was as high as 1,200lb. to the square inch at a vertical depth of 1,392 feet.

Up to this time the practice had been to clean the column by way of taking out two lengths of piping at a time and replacing by spare lengths. The furred lengths were removed to the surface and then cleaned as well as possible by various designs of scrapers. This method proved very tedious and, when we think of present pumping costs, very costly. The method in fact proved practically ineffective, as the column could not be cleaned quickly enough to show any appreciable difference of pressure at pumps.

As an experiment a new method was tried, namely, the inserting of two brass balls of five and three diameter in the pump column at shaft collar, whilst pumps were at work. The balls were attached, each other, as per sketch, the



smaller ball entering the column first, and a wire was attached to the rod behind the larger ball, with the idea of withdrawing the balls quickly in case of emergency. The action of the balls was, to say the least, surprising, but after travelling a short distance the wire broke.

On finding that the pressure at the seventeenth level had not increased, but had slightly decreased, it was decided to let the balls take their course. A careful watch was kept on the pumping plant throughout this experiment. In twenty days, or, say, 420 pump hours, the balls travelled a distance of 1,739 feet. They were removed at the fourteenth level, and a smaller set of balls—3½ in. and 2½ in. diameter—inserted to suit the smaller columns. These took eight days to travel to the seventeenth level, when they were removed. It was found, on examination, that the column was thoroughly cleaned throughout, the wood lining not being damaged, the pressure at pump on seventeenth level with all pumps working was actually under 650 lb. to the square inch.

As regards the action of the balls while at work in the column, one was reminded of a loose non-return valve being lifted regularly off its seat at very short intervals, the difference of course being that the balls formed two rough seats, had no guide, and were consequently kept moving within the whole area of column. The position of the balls could be easily ascertained at any time (providing that there was not too much noise in the shaft) by their constant knocking in column while pumps were working.

It is interesting to note that the light sediment was washed past the balls and deposited at column outlet on surface, while the heavier sediment was washed out in the blowing down of the column.

The precaution to be taken is, if pumps are going to be stopped for any length of time,

column ought to be blown down, as sediment might settle and choke column.

It need hardly be mentioned what an important factor on pumping costs the above changed conditions have brought about, and not only has this change reduced pumping costs, but it has allowed also for a reduction of the number of men employed on such work. The saving in worry and supervision is one which must appeal to all.—BLYTH, *South African Engineering*, from *Trans. S.A. Inst. of Engineers*, September, 1921, page 175. (A.K.)

MINERS' CONSUMPTION.—Technical Paper 260 of the U.S. Bureau of Mines is devoted to the preliminary report of an investigation made by Dr. A. J. Lanza, of the U.S. Public Health Service, and Daniel Harrington, of the Federal Bureau of Mines, regarding Miners' Consumption in the Mines of Butte, Montana. The following recommendations are made:—

(1) Dry drilling should be absolutely eliminated. Spraying devices should not be used with dry drills, as they are very likely to be inefficient, due largely to the fact that the co-operation of the miner is required to obtain maximum efficiency, and only too frequently this co-operation cannot be relied upon. Tests of spraying devices prove that when used with judgment such devices may afford considerable protection to the driller and his associates, but investigation of the actual use of sprays has shown that the miner only too often handles a spraying device so as to actually increase the danger to himself as compared with dry drilling.

Elimination of dry drilling is largely a question of drilling fewer upper (practically vertical) holes; wet drills (Leyners and wet stopers) can readily be employed in the drilling of all holes except those pointed vertically upward or not more than 30° from the vertical. It would seem feasible to use the wet drills in all kinds of places in Butte mines, except possibly raises, and even raises have been driven in Butte with Leyners when the rock was too hard for the stopers. Where raises are of such small area that the handling of Leyners would be cumbersome water stopers can be used. Miners object to the latter because of water from the drill holes wetting their clothes, yet miners do not object to using Leyners in drifts and crosscuts, although few shifts pass without the machine men having their clothes, and especially their shoes, saturated with water. Moreover, men working in most raises in Butte have their clothing saturated with perspiration. By the use of judgment in handling Leyners or water stopers the drillings from upper holes can be made a comparatively thick mud that has little tendency to fall on the driller, so that the use of wet drills for upper holes becomes largely a question of educating miners in proper regulation of water feed and of enforcing the use of wet drills.

(2) All working places underground, including drifts, cross-cuts, stopes and raises should be piped with water, preferably pure city water under pressure; the successful use of water drills depends absolutely on all places being piped with water, as miners cannot be expected to carry water into raises or stopes for drilling. This water could be used for drills in all kinds

of places, for wetting down muck piles, shoveling, and also to aid in lowering the high temperature of the mine. Possibly wetting of muck piles might have to be discontinued during cold weather to prevent excessive freezing of ore in surface-ore bins and in railroad cars.

Water should also be used to spray the mouths and possibly the entire length of ore chutes; skip chutes should be sprayed as well, especially where the skip chutes are at downcast shafts; where dry ore is handled in downcast shafts a complete system of water sprays should be used in air courses leading from the shaft. In addition, water should be used freely in sprinkling the floors, sides, and top or back of haulage ways, shaft stations, and manways at all times of the year.

(3) All firing of shots while the shift is at work should be eliminated; if such elimination is impossible and shots are fired, no men, except possibly "fire bugs," whose work is of an emergency nature, should go into the place for at least three hours, unless the place has been well sprinkled immediately after the shot-firing or before any work is done there. This is important, as the shock to the air from the firing of shots throws clouds of excessively dangerous fine dust into the air; this dust settles very slowly, especially where air movement is sluggish; moreover, some of the gases from explosives are poisonous.

(4) In order to decrease the temperature and humidity of the air at working faces and to remove dust and poisonous fumes, especial effort should be made to increase the circulation of air at the places where the men are working and not to allow it to be dissipated in abandoned working or to traverse only drifts and crosscuts that are largely unfrequented by workmen. To ensure such circulation the underground work should be concentrated as much as possible, thus eliminating the large number of levels to be ventilated; all places that have been abandoned, including drifts, manways and stopes should be sealed off by concrete stoppings by doors, or otherwise, downcast air should be divided into a definite number of splits and an effort made to keep the total quantity of air in each split concentrated so as to maintain as high a velocity as possible. Splits for drifts and crosscuts in the Butte mine should carry 12,000 to 20,000 cubic feet of air per minute. At intervals there should be raises or manways comparatively close to working places and cleared of obstructions, such as chutes and platforms, so as to permit air to pass with minimum friction, and all air courses should be kept clear to allow free passage of air. Idle cages or skips should not be allowed to remain in shaft, nor should cars, timber, etc., be allowed to practically seal room air courses as they do in many places. Mine air should not be allowed to discharge into downcast shafts to vitiate fresh intake air, and air should not be taken from upcast shafts to ventilate parts of the mine. In other words, all possible effort should be made to concentrate air currents, concentrate them to flow through the working places with minimum hindrance, and then to be discharged from the mine as quickly as possible.

For deflecting air-currents underground a more extended use of doors, of fireproof canvas and brattice, and of regulators is recommended. On haulage roads a type of door should

be used that can be relied on to close automatically and allow minimum leakage of air. The free use of small electrically driven fans with canvas pipe is commended, provided suitable safeguards are taken to make installation fireproof; such fans and canvas pipe could force air through high raises or long drifts or crosscuts to the working face, doors and brattice being used to deflect air-currents to places where men work in stopes, drifts, etc., that are comparatively close to the air-courses.

If the mine is piped with city water, as heretofore recommended, water sprays could be advantageously introduced into air-currents in drifts, cross-cuts, etc., and into canvas or galvanised iron ventilating pipe in order to decrease air temperatures. Comparatively small quantities of cool water sprayed into air-currents have well-defined cooling effect, and this is particularly true of air being transmitted through ventilating pipes; sprays also aid in settling fine dust. The spraying, as far as practicable, should be constant rather than intermittent.

In so far as is feasible, each mine should be ventilated independently of adjoining mines, and should have at least two shafts, one an upcast and one a downcast, to the lowest workings. Where possible ventilating shafts should be smooth-lined and fire-proof and offer minimum obstruction of air-flow. All mines should be ventilated by a fan or fans of large capacity; main ventilating fans should, where possible, be on the surface, housed in fireproof structures, and be readily reversible. Very important fans should have more than one source of power, such as steam and electricity or alternating and direct current motors, etc., so arranged as to cause a minimum amount of delay in going from one source of power to the other in case of failure of one kind of power; this is especially important at time of fire or other disaster. Fans should be kept in operation twenty-four hours per day, even when full shafts are not working.

(5) Provision should be made so that, at least in winter, it will not be necessary for miners coming off shift in wet clothing to stand in line in the open air in order to give their time. The time-keeper should receive the time in the "dry" or in some other building where miners waiting turn would be protected from the weather. It also seems feasible to have a fireproof runway, covered and possibly heated, extending approximately from the shaft collar to the wash-house or "dry," so that underground men emerging from the mine in winter need not be exposed to the weather. A. J. Lanza and D. Harrington, *The Science and Art of Mining*, page 91, October 15, 1921 (J.C.)

MISCELLANEOUS

THE EFFECTS OF SCRATCHES IN MATERIAL.—Professor E. G. Coker, M.A., D.Sc., introduced this subject at the Engineering Conference in London. He said that the importance of having a smooth surface in metals exposed to a high stress had been recognized by many engineers, who impart a high degree of finish to their work, especially in cases where an intense stress varies cyclically, as in the moving

parts of high-speed machinery. The increased strength and extension due to a high degree of polish in a tension test-piece had also been frequently noted, and the elimination of scratches appeared to be of importance in many other cases.

He continued: "The effect of a surface scratch in a stressed material is therefore a problem of great interest and in general of considerable perplexity. It is probable that little is lost by making as simple assumptions as possible in examining this problem, and in the great majority of practical cases it seems likely that the scratches produced by ordinary machining operations may be considered as minute notches in the surface, probably with plane or curved sides inclined at a considerable angle and rounded off at the bottom of the notch by curves with radii much greater than the average size of the unit of crystalline structure of the metal. For ease of experimental investigation the effect of a scratch or group of scratches may be studied with advantage in a transparent body. If, for example, a scratch is made in the edge of such a plate under tension or bending stress, the stress concentration produced can be observed, and if the mean tension is, say, one-third or even less than that of the yield point of the material, it is usual to observe signs of over stress at the scratch; while, if the load is alternating, these indications gradually penetrate farther and farther into the material, apparently along planes inclined at 45° to the line of pull in ductile bodies—that is, along the planes of maximum shear stress.

"In a group of scratches sufficiently close to affect one another, the combined result is, naturally, still more noticeable, and the failure of a material under a comparatively moderate mean stress, due to surface scratches, is not difficult to understand, especially if the loading is of an alternating kind.

"The form of the scratch produced is all important, and a comparative estimate of various types can be easily obtained without the complications of microscopic examination by examining notches on the large scale under conditions in which the influence of boundaries other than those of the notches themselves, are practically unimportant. If this is done it can be shown, for example, that a scratch producing a semi-circular groove in the material may raise the stress to about double the average stress, while a groove with straight sides at 45° and a radius at the apex of one-eighth of the depth gives an increase of rather less than five times the mean stress, according to the recent measurements of one of the author's research students, Dr. Paul Heymans.

"Increased sharpness of curvature at the bottom of the notch produces still greater local stress, and this latter may easily cause a fine crack to develop and produce failure owing to its rapid extension into the material caused by the abnormal concentration of stress at the extremities far transcending the ability of the material to bear, even if it approached the tenacity which it seems possible it might have from calculations of intrinsic pressure, and, in the absence of cracks, flaws and cavities."—E. G. COKER, *Industrial Australian and Mining Standard*, October 6, 1921, page 639. (C.J.G.)

HOW ENGINEERS ARE FERRETING OUT JOBS IN NEW YORK.—The Employment Bureau of the Federated American Engineering Societies, conducted, under the direct supervision of the secretaries of the four Founder Societies, has wanted to extend its activities and usefulness, but it is operating right up to the limit of its budget; consequently, anything which requires the expenditure of more funds cannot be undertaken for the present. A great deal of time has been spent in recording, classifying, and interviewing the men listed, but owing to the business depression, only a comparatively small number of men have been placed during the last few months. There are men in New York from all over the country. What the Bureau needs is more positions available.

With this in view, a number of high-grade engineers, themselves in need of employment, volunteered their services for a publicity campaign in the City of New York. A definite mode of procedure was evolved, and the success of the movement has been considerable. Following is a chronological arrangement of the methods used:—

(1) A committee limited in membership to twelve men was selected from the best available men among the unemployed, to be representative of the high standards of the societies. This committee is self-supporting and self-perpetuating.

(2) The committee made a complete alphabetical card index of all consulting engineers and all firms in the City of New York in which there were one or more members of the societies. Then a record list was made, classified according to the geographical location of the offices in order to facilitate the calls. For the purpose of uniformity, a definite policy in regard to the work was drawn up.

(3) The members of the committee were assigned districts to work in, and a personal call was made on each firm and individual in the district with the purpose of advertising the Bureau. Calling cards and report blanks were furnished these men. The reports are made in duplicate and one is placed with the proper card on each of the two indexes.

The result to September 12th are compiled in the following table:—

Calls made	2,263
Interviews	1,335
Bureau unknown to	576
Prospective positions	65
Actual positions	56

The disparity between the number of calls and the number of interviews is to be explained by:—

(a) Members or firms moving away from New York City.

(b) Members or firms going out of business.

(c) Member out of town and no one in responsible charge of office.

Although the committee has practically completed the making of the calls for which it was originally organised, it is not ready to present its final report until a further study and analysis is made of the results obtained thus far. The committee also contemplates carrying on certain further work as follows:—

(1) Remaining calls in Brooklyn.

(2) Calls on bankers.

(3) Return calls on prospective employers.

(4) Extension of publicity work to non-

engineering business.

(5) Formation of sub-committees to call upon employers in the suburbs.

It should be noted that a number of vacancies have been found, and inasmuch as the prospective jobs refer to actual needs within six weeks, these should be classified as jobs available for statistical purposes. Since the men who knew of the Bureau used it, all the jobs, actual and prospective, came from members who were not aware of this service. Therefore 35 per cent. of the establishment called upon, which had never heard of the Employment Service, furnished these vacancies. There is evidently a great need, even in this period of depression, of bringing the man and the job together.

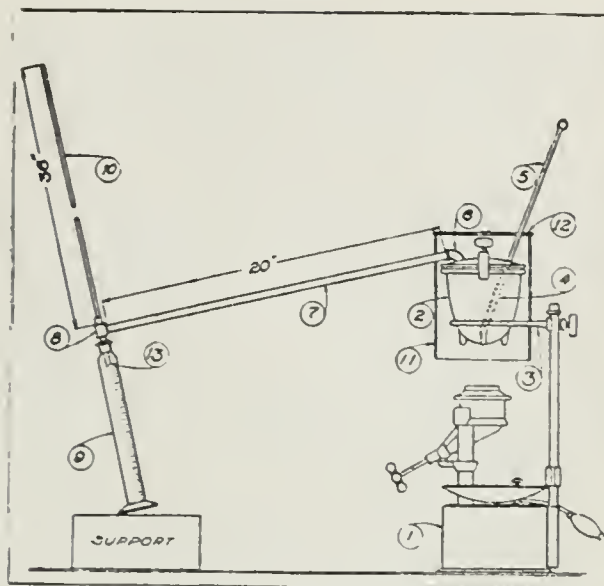
In view of the surprisingly good results thus far obtained, it is hoped to supplement the personal calls by sending out a circular letter to all employer members of the societies, while these calls are being made.

Enquiries are received from many employers from various parts of the country, and those enquiries are in most instances promptly filled by the Bureau. The volunteer committee in New York is finding opportunities for men outside of New York—*Mining and Metallurgy*, October, 1921, page 12. (C.J.G.)

PETROLEUM—Petroleum or gas is now being found in three out of four wells drilled in all proved fields of the U.S.A. In some fields the proportion of dry wells is but one out of ten. Geologists, studying territory, are correct in their forecasts or conclusions as to the presence of oil in 87% of their reports—F. WAXTEUNER, *Financial Ledger*, Philadelphia, September 23, 1921. (F.W.)

RETORT FOR ASSAYING OIL SHALES FOR OIL YIELD—The retort, which was developed through experimentation in the United States Bureau of Mine's laboratories, is recommended as a simple device by Mr. L. C. Karick in the Bureau's report of Investigation No. 2228 for field and laboratory use where rapid assays are desired with results of duplicate tests agreeing within 1%. In setting up the apparatus, great care must be exercised to see that it is airtight. It is important to use a sheet-metal jacket around the retort when heating, leaving about a quarter of an inch clearance at the sides and enough to clear the clamp screw on top. Notches are cut in the jacket for ring support and delivery tube. A cover of asbestos boards is necessary to reflect heat down against the retort lid, otherwise oil will condense on the inner side of the lid and drip down on to the shale in the retort, thus causing losses by secondary distillation.

Crack the shale to pass a quarter of an inch screen, and weigh out just enough to fill the retort (2) level full, permitting the chance to run freely in the retort. After the lid is fastened carefully in place and tested for leakage, place the retort on the ring support (3), adjust (9) (11) and (12), start the burner (1), then fasten the graduated cylinder (7) and reflux condenser (10) tightly in place. Use a very small flame at first, so that no oil will appear within 15 minutes after starting.



OIL SHALE ASSAY RETORT.

1. Dangler lamp.
2. C.I. mercury retort (1 pt.).
3. Ring stand.
4. Thermometer well.
5. 400° Cent. thermometer.
6. Standard W.I. street ell.
7. 1/4-in. standard W.I. pipe.
8. Standard W.I. tee.
9. 100 c.c. graduate.
10. 1-16th in. I.D. pyrex tubing.
11. Sheet iron shield.
12. Asbestos cover.
13. 1/4-in. pipe nipple, cut at 15° angle.

Before distillation makes any considerable progress the interior or coolest shale should be at least as hot as the vapourising temperature of the oil evolved, otherwise vapours will migrate to the central or coolest part and condense there, causing losses of oil by cracking on re-distillation of the condensed oil.

When 2 c.c. or 3 c.c. of oil have accumulated, the flame should be increased; it is imperative to distil rapidly after oil vapours begin. If oil first appears in about 45 minutes it will then be safe to double the size of the flame, and thereafter every 20 to 10 minutes increase the heat by an equal amount.

With the average oil shale, the recovery when the actual oil producing period is approximately two hours, will be 5% greater than when distillation lasts six hours. When distillation is completed in less than two hours, there is danger of inaccuracy from exceeding the condenser capacity, and undoubtedly, from decomposition of oil vapours by excessive temperatures. Distillation should be rapid enough, however, to prevent stagnation of oil vapours within the hot retort or connection, and should progress at a uniform rate. If oil droplets appear dangerously near the top of the reflux condenser (10), the rate of heating must be retarded slightly.

If retorting has progressed correctly, the rate of oil accumulation will decline suddenly as the last oil is distilled off, and when this cessation becomes apparent, the flame should once more be increased the usual amount. A white gas may appear at the end of the run, but this has been found to be non-inflammable and to carry no oil vapour. The delivery tube should be

kept fairly warm throughout the run, to prevent the oil from congealing therein. When the bottom of the retort has become a dull red, it be safely assumed that the distillation of oil is completed, as this temperature is well above the final oil-yielding temperature of all oil shales.

The stoppered graduate and contents must be warmed until the oil is in a very fluid condition. Allow the oil to settle well, as some water is given off near the last stages of distillation, and will remain suspended in the partially congealed oil. In order to read accurately the volume of the oil and water, it is necessary to assist the formation of a perfect meniscus by releasing any oil and water clinging to the sides of the graduate. This is best accomplished by revolving the graduate, while still warm, between the palms of the hands. Read the upper level of the oil and then the lower level, if it is well defined and is not rendered obscure by emulsion, sediment, or clinging oil and water. The following procedure will facilitate accurate reading of the lower meniscus, and also provide against the possibility that water sediment may not have settled out completely. Draw off with a pipette all except a few cubic centimetres of the oil while still warm, dilute the remaining oil with 10 c.c. to 20 c.c. of clean gasoline and agitate gently till the emulsion disappears. Allow the shale oil and gasoline solution to settle, then draw off and add gasoline as before. Repeat as often as required, until a clear meniscus results. From the number of cubic centimeters of oil collected, calculate the gallons of oil per ton of shale.—L. C. KARRICK, in Report of U.S. Bureau of Mines; *The Colliery Guardian*, page 728, September 9, 1921. (F.W.)

PURIFYING AIR BY ELECTRICITY.—The well-known French scientists D'Arsonval, Bordas and Touplain have examined into the possibility of clearing air of solid and liquid particles, as well as the micro-organisms which are found in suspension, by electric means. Experiments have been made with a glass or copper tube of 20 centimetres diameter, and one metre in length, with an axial wire connected with a high negative potential by a continuous current of 25,000–30,000 volts. This current at high tension is obtained by a special arrangement for producing currents of high frequency, a process mentioned by D'Arsonval, and modified in obtaining X-rays. Experiments in which air polluted with a mineral dust sterilised and seeded with *Micrococcus Prodigiosus* was made to pass over this arrangement, showed that under these conditions, while the control gave 150 colonies per cubic metre on the average, the air submitted to the action of a current of 5,000 volts became absolutely sterile. These results are not in agreement with those of the authors in their experiments on the purification of solid particles. The best yields obtained did not exceed 95% to 97%. The authors also have to admit that the action of ozone must intervene in the destruction of the microbic germs.

Estimations made having shown quantities of ozone to the extent of about one milligram per cubic metre at the exit of the apparatus, subsequent researches should permit of definitely fixing the part played by the ozone in

this electric purification, as well as the mechanical influence of the flow of water on the inside of the tube. The principal part of the apparatus used in the above-indicated experiments consisted of a copper tube, the inside of which is kept moist by a continual flow of water.—*Compte Rendue de l'Acad. d. Science*, 1920, page 646; *Ind. Aus. Min. Stand.*, September 8, 1921, page 455. (C.J.G.)

INDUSTRIAL RESPIRATOR.—At a meeting of the Society of Chemical Industry, in London, Dr. L. Levy and D. W. West, in discussing the industrial respirator, said that it consists essentially of two parts: a face-piece and an absorption apparatus. The face-piece may consist only of a mouth-piece and nose-clip, but this form causes much discomfort and affords no protection to the eyes. The second and more recent form is a complete mask of rubber fabric with eye-pieces of glass so arranged that the incoming air passes over the inner surface of the glass, thus preventing dimming by moisture from the breath. This form requires neither the use of a mouth-piece nor of a nose-clip, and may be worn for a much longer period than the former type. The purifying canister is of the form used in the small military box-form respirators, and the substances employed for absorption should have a high capacity and rate of re-activity for the gases to be removed from the inspired air. The absorbents used vary according to the toxic substance to be dealt with; crystalized copper sulphate, highly activated charcoal, and a mixture of alkali and charcoal powder are used, respectively, for ammonia, hydrocarbon and other neutral gases, and acid gases. A satisfactory means of removing smoke and solid particles is a mask of fine felt, fitted with an efficient non-return valve for the egress of the expired air. No absorbent for carbon monoxide is known that is suitable for use in a respirator, and, therefore, the catalytic oxidation of this gas by oxides is employed. But this method has certain disadvantages, for example the harmful effect of moisture upon the catalyst (which may be overcome by a preliminary passage of the gas through calcium chloride), the absorption of a portion of the atmospheric oxygen to oxidize the carbon monoxide, and the absence of any indication of failure in the respirator. The last-named defect may be remedied by using an upper layer of iodine pentoxide and sulphuric acid which, when any carbon monoxide unoxidized by the catalyst is absorbed, liberates free iodine vapour that acts upon the throat of the wearer and thus indicates the breakdown of the purifying medium that is used.—*Mining and Scientific Press*, page 338, September 3, 1921. (C.J.G.)

CHANGES OF ADDRESS.

- BOYD, J. A., *110* 257, Bertha Street, Kenilworth; 185, Smit Street, Johannesburg.
 AYMARD, M., *110* Care of The Technical Bookshop, Salisbury House, London; Care of Cox's E.A.F. Bank, 16, Charing Cross, London, S.W.1.
 ROME, A. S., *110* Rezende Mines, Ltd., Penhalonga, S. Rhodesia; Care of The Cam and Motor Gold Mining Company, Ltd., Eiffel Flats, Rhodesia.

117

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THE COMBUSTION OF SOUTH AFRICAN COALS IN BOILER FURNACES.

By E. P. REIM, B.Sc.

Origin.—In considering the combustion of coal for any particular purpose a knowledge of its origin and mode of formation is useful. In Transvaal coals one frequently finds traces of organic origin such as portions of fossil plants, and carbonised vegetable remains (v. Microphotograph 1), which when splintered and digested with Sodium Carbonate, show under the microscope vegetable cells (v. Microphotograph 2), which in this case are dotted with scars typical of Conifer Wood.

Regarding the mode of formation of coals, the "Drift" Theory supposes that at a period when plant growth was very prolific a great amount of vegetable matter was carried by floods into lakes or the sea, and this accumulated in banks at the lake or sea bottom, at a later period strata of sedimentary rock were formed above the accumulation, and, from time to time, the whole was subject to the upheavals and subsidences of the earth's crust, the pressure and heat accompanying these changes with the heat generated by the decomposition of the organic matter, transforming this organic matter into coal, the lower layers, which were subjected to the greatest heat, being usually anthracitic, while the volatile matter was driven to the upper layers. The Natal anthracite is derived by heating from intrusive rocks. The many exceptions to this arrangement show that this theory is not complete, though some contend that the differences in variety of coal are more due to variations in the original organic matter than to heating. The "In Situ" Theory supposes that coal was formed as one can see the process going on at the present day in tropical swamps or in peat bogs, where vegetable matter grows profusely, and where growth and decay are a continuous process.

The plant remains are decomposed by bacteria, and the resulting organic matter collects on the clay bottom of the swamp or bog as a slime, at a roughly estimated rate of 8ft. in 1,000 years under present-day conditions; the final change of the slimy organic matter into coal is supposed to take place through regional metamorphism, similarly to coal formed by the "Drift" method, when strata of rock are formed above it, and the whole is subjected to pressure and heat. It is estimated that an 8ft. thickness of organic matter is reduced to an 8in. seam of coal. If coal formed by the "In Situ" method has not been subjected to excessive heat it is likely that the upper layers would be anthracitic, as it would chiefly consist of the partially decomposed surface vegetation, while the lower layers derived from the slimy ooze would be higher in volatile constituents. The majority of coals must have been formed by either or both of these methods. The Transvaal coals are accepted to have been formed by the "In Situ" method. Microphotographs 3 and 4 show the microstructure of a specimen of petrified wood from Apex Colliery. In the former one can see the arrangement of the tree cells with the annual rings, and in the latter, which is more highly magnified, one can see what I judge to be the remains of the micrococci that were eating away the tree, my reasons for this opinion being that they are all similar in shape and size, and show their typical arrangement, namely, they occur singly, then undergoing the process of division, then in colonies (v. Microphotograph 5) also I have compared these with a microphotograph after Renault showing *Micrococcus Zeileri*, a bacterium in the epidermal cells of the bark of a *Bothrodendron* from the Toulou coal (Upper Carboni-

ferous) of Russia. Certain vegetable cells such as pollen cells can resist bacterial attacks, and one can discover them on digesting splintered coal. In the "Drift" method, if the accumulation were formed in deep water, bacterial action could not take place, as micro-organisms cannot live at depths not reached by the sunlight.

Impurities.—The impurities in coal are of two types, namely, those deposited during the formation of the coal in the form of mud or sand, consisting largely of Silica and Alumina, and including, chiefly in the dull portions, woody ash (v. Microphotograph 9), and secondly, those deposited subsequently, usually between cleavage planes, derived from solutions soaking through the coal: under this class come Calcium Carbonate (v. Microphotograph 7) and Pyrites (v. Microphotograph 8). In Witbank coal the pyrites usually occurs in large pentagonal crystals or in clusters of smaller crystals; but in Apex coal, though one occasionally finds small pentagonal crystals, the pyrites is usually of a fibrous appearance and has been derived from solutions containing Ferrous Sulphate soaking through partially decomposed wood, which reduces it to FeS_2 , this taking up the form of the tree cells; the fibrous appearance can be seen in Microphotograph 8, which is similar in appearance to the Conifer Wood remains shown in Microphotograph 1. In Oogies coal I found a specimen in which the pyrites had taken up the form of a *Pachypteris* leaf (compare Brogniart Plate 45 with fig. "a").



Fig. "a." Natural Size.
Impression from *Pachypteris* leaf from Oogies Coal.

Combustion.—An analysis of coal from the Apex Springs series is:—C — 58.89%; H — 3.80%; S — 1.50%; N — 1.4%; H_2O — 3.41%; O — 10.00%; Ash — 21.00%.

The oxygen in the coal is assumed to be combined with hydrogen in the form of water (which water must exist in the coal in a combined state, as it is not driven off by ordinary drying at 100°C .), the reason for this assumption being that the affinity between hydrogen and oxygen is greater than that between oxygen and any of the other constituents of coal, as evidenced by their greater heat of combustion. Thus, in a coal having the above analysis, the hydrogen percentage should be reduced by an amount obtained from the equation $\text{H}_2 + \text{O} = \text{H}_2\text{O}$, namely $2/16$ of 10.00% = 1.02%. The hydrogen percentage then becomes (3.80 — 1.02)% = 2.78%.

One should be able to obtain the calorific value of the coal by multiplying the weight of the combustibles per pound of coal by their separate calorific values, thus:—

Carbon	58.89	\times	14,540	=	8,540 B.Th.U.
Hydrogen	2.78	\times	52,830	=	1,470 B.Th.U.
Sulphur	1.55	\times	4,032	=	60 B.Th.U.
					10,070

In practice it is found that the calorific value of a coal determined experimentally is lower than that given by calculation, the difference being due to the Carbon, Hydrogen, and Sulphur being present in the coal in complex forms. It is probable also that the Fixed Carbon even is present in not altogether its free state, and heat is lost in bringing about the dissociation of these compounds. Empirical formulae are sometimes used for obtaining the calorific value of coal from its ultimate analysis, such as the following:—

$$\text{Calorific Value (B.Th.U.)} \\ = 146.5\text{C} + 621\text{H} - 54(\text{O} + \text{N})$$

where C, H, O and N represent the percentages of carbon, hydrogen, oxygen and nitrogen respectively. However, the calorific values of coals are practically always determined experimentally, and average values for Witbank coals are 12,000 B.Th.U. per pound of coal, and for Apex coal 9,000 B.Th.U. per pound of coal.

The stages that coal goes through in a boiler furnace are as follows:—First, the moisture is driven off as steam, and is carried off, chemically unchanged, with the waste gases: at some steaming stations the

coal is moistened before feeding it into the boilers, with the idea of keeping the fines from falling through the grate, but this moisture will all be driven off before the coal reaches a sufficiently high temperature for the formation of Water Gas, so in the combustion this water acts only as a diluent. Microphotographs 9, 10, 11, and 12 show the distribution of the incombustible matter, the fixed carbon and the volatile matter in different varieties of coal, and help one to visualise the subsequent changes that take place in the boiler furnace: first, the volatile matter boils and distills off, the gas pressure cracking the coal where there is any weakness such as between the different layers in banded coal (v. Microphotograph 13); the incombustible matter and fixed carbon, if small in size, will float about the boiling matter, and as this distills off the particles will cohere and give a cellular or ribbed structure (v. Microphotograph 14); if the incombustible matter and fixed carbon is larger in size and more compactly arranged, as in the dull bands, the volatile matter will merely force itself through the gaps, and when these are not big enough it will crack the coal (v. Microphotographs 15 and 16); a certain amount of the volatile matter will decompose and give a shiny carbon deposit on the incombustible matter or on the fixed carbon, such as one sees in coke. Through the spaces now in the coal the air penetrates, and the oxidation of the carbon is carried out. When the volatile matter distilled off it was carried through the archway and the combustion chamber, and there if the temperature is sufficiently high and the combustion chamber is large enough to allow the gases sufficient time, they are completely oxidised before impinging on the relatively cool boiler tubes. In this connection the forced or the induced draught systems are an advantage, as, with the increased air velocity, a smaller percentage of excess air will suffice, thus giving a greater furnace temperature. At a steaming station where induced draught is used and where the furnace temperatures are never less than 2000°C , there are no signs at the smoke stack of any incomplete combustion, but where the furnace temperatures are lower than 2000°C , which one gets with furnace-sparking on natural draught and with too small combustion chambers, there are signs of unburnt gases and unburnt carbon particles at the smoke stack.

Regarding the ash, if this is fairly heat resisting, such as that containing chiefly

silica and alumina, and if it is compactly distributed, it will retain its original shape, as is the case with the dull portions of Apex coal; but if it is present in smaller particles and more widely distributed, it will be carried away with the draught when the carbon around it is oxidised away, as is the case with the bright bands in Transvaal coals, from which there is a fair amount of this fine ash, and provision has to be made for removing it from the end of the combustion chamber and from the flues. If an ash is not a good heat resister such as that containing a fair amount of lime or pyrites, it will fuse and form clinker; pyrites also has the disadvantage that it accelerates the corrosion of the grate links or fire bars, by forming ferrous sulphide in between the crystal grains of the iron. Microphotograph 6 shows a piece of C.I. grate link which was heated in contact with pyrites in a furnace; the greater part of the pyrites, though, is oxidised to SO_2 and carried away with the flue gases, and when this or the hot ash containing some unburnt pyrites comes into contact with moisture, Sulphurous Acid is formed, which, of course, has a very corrosive action on iron such as the roofs of surrounding buildings.

Ash in coal, especially when it reaches high percentages such as in Apex coal (25%) is a disadvantage as, besides taking away a relatively small amount of heat to the ash pit, it prevents, mechanically, the complete combustion of the carbon, which is a serious consideration; in the dull portions of Apex coal, for example, which is very high in ash (v. Microphotograph 9), the carbon is often oxidised only to a depth of $\frac{1}{2}"$ or $\frac{3}{4}"$ below the surface, and then the protective layer of ash prevents further oxidation. (v. Microphotographs 15 and 16). One also gets the same effect with a very fusible ash, when a layer of liquid ash will form around the coal and prevent the air from getting at the surface (v. Microphotograph 17). By increasing the exposed surface of the coal relative to the volume this effect is lessened. In Table I are shown values for the ratio of area to volume for coal of different sizes, assuming the coal to be cubical, from which it will be seen that if the coal is broken up from 6" cubes to 01" particles, the exposed surface is increased 600 times, in which case the effect of the ash upon combustion will be negligible, which condition is obtained in Dust Fuel boilers. It is rather surprising that Dust Fuel boilers are not more popular with users of coal of high ash content, as

in addition to the more perfect combustion resulting from a larger exposed surface the mixture with the air is much more intimate, and so comparatively little excess air will be required. Of course Dust Fuel boilers have their disadvantages, such as the quicker choking up of the flues and the cost of pulverising the coal: the cost of pulverising the coal is estimated at about 6d. a ton. However, the carbon value in the ash of a coal having, say, 25% ash and costing 7/- a ton will be about $1/5$ per ton of coal burnt, so the cost of pulverising is only about one-third of the value still in the ash. This figure is obtained as follows:—In the ashes there will be about $12\frac{1}{2}\%$ of the original weight of the coal of unburnt carbon, whose calorific value relative to 1lb. of the original coal will be $(12.5 \times 14540) \div 100 = 1820$ B.Th.U., and taking the calorific value of the coal at 9000 B.Th.U., the percentage lost in the ash will be $(1820 \div 9000) \times 100 = 20.2\%$ of the value of the coal, i.e., 20.2% of 7/- = $1/5$. The disadvantages of Dust Fuel boilers are not really serious, and their more general adoption should be expected. A possible further application of Dust Fuel boilers is in connection with the removal of the bye-products from coal before using it as fuel; the coke obtained after removing the bye-products is not suitable as a fuel in the ordinary type of boiler furnaces, but pulverised coke can be used efficiently in Dust Fuel boilers.

Another development in the use of pulverised coal is as Colloidal Fuel, i.e., pulverised coal and fuel oil mixed with small quan-

ties of a third substance which keeps the coal particles in suspension, and this is sprayed into the furnace; this arrangement, however, is not an advantage in a country to which oil has to be imported, and, in any case, its advantages over the ordinary Dust Fuel boilers are doubtful.

The carbon contents of the ash from the ordinary types of boilers using semi-bituminous coal is about 50% of the ash content of the coal; thus in a station where the average ash content of the coal is 20% this will take away with it 10% of the original weight of the coal of carbon. This percentage can, of course, be decreased by increasing the excess air and lowering the CO_2 percentage and furnace efficiency. The author has suggested carrying out experiments with a view to reducing the carbon percentage in the ashes, by allowing hot ashes to collect on top of the tippler and then passing steam slowly through them from underneath; this steam should diffuse through the cracks in the ashes and combine with the hot carbon to form water gas according to the formula $\text{C} + \text{H}_2\text{O} = \text{CO} + \text{H}_2$.

Combustion (theoretical weight of air required per lb. of coal).—Consider the case of Witbank coal having an analysis:—C = 66.45%; H = 4.17%; S = 1.55%; O = 8.05%; H_2O = 1.05%; N = 1.20%; Ash = 17.53%. The percentage of hydrogen will have to be reduced by $2/16$ of 8.05 = 1.0%; the hydrogen percentage then being 3.17%; this being to allow for the 8.05% of oxygen.

Carbon. ($\text{C} + \text{O}_2 = \text{CO}_2$) 12 lbs. carbon require 32 of oxygen
 $(12 + 32 = 44)$ 66.45 lbs. „ „ $(32 \div 12) \times 66.45$ of oxygen = 1.77 lbs. of oxygen.

Hydrogen. ($\text{H}_2 + \text{O} = \text{H}_2\text{O}$) 2 lbs. hydrogen require 16 lbs. oxygen
 $2 + 16 = 18$ 0.317 „ „ $(16 \div 2) \times 0.317 = 0.25$ lbs. of oxygen.

Sulphur. ($\text{S} + \text{O}_2 = \text{SO}_2$) 1lb. of sulphur requires 1lb oxygen
 $(32 + 32 = 64)$ 0.155 „ „ say 0.2 lb oxygen

Oxygen required to burn carbon in 1 lb. of coal	1.77 lbs.
Oxygen required to burn hydrogen in 1 lb. of coal	.25 lbs.
Oxygen required to burn sulphur in 1 lb. of coal	.02 lbs.

Total ... 2.04 lbs.

23 lbs. of oxygen are contained in 100 lbs. of air
 2.04 „ „ „ „ $(100 \div 23) \times 2.04$
 = 8.9 lbs. of air.

Thus, Witbank coal requires for combustion 8.9 lbs. of air. And similarly, Apex coal requires for combustion 7.7 lbs. of air.

Combustion (temperature of combustion).—

Witbank coal. Products of combustion:—

1 lb. coal requires 8.9 lbs. air containing	(77.100) × 8.9 lbs. nitrogen
	= 6.85 lbs. nitrogen
Nitrogen contained in 1 lb. of coal	= .01 lbs. ..
Total nitrogen	= 6.86 lbs. ..
2 lbs. of hydrogen is contained in 18 lbs. of steam	
.0417 .. ..	.38 lbs.
Moisture in coal	.01
Total steam	.39

To burn .6645 lbs. of carbon there is required 1.77 lbs. of oxygen, this resulting in (.6645 + 1.77) lbs. of CO₂ = 2.43 lbs. of CO₂.

To raise the products of combustion of 1 lb. of coal 1° F.:—

	Weight.	Sp. Ht.	B.Th.U
CO ₂	2.43	.216	.526
H ₂ O ... ..	.39	.475	.185
N ₂	6.86	.244	1.673
Ash ... ..	.16	.200	.032
Total ...			<u>2.416</u>

Average calorific value of coal 12000 B.Th.U.

Average boilerhouse temperature 86° F., 30° C.

Theoretical Temperature of combustion ... = $12000 \div 2.416 + 86^{\circ} \text{F}$
 = 5060° F = 2800°C

With 50% air dilution:—

Weight of air 4.45 lbs. × Sp. Ht. .237 ...	= 1.054	B. Th. U.
Heat for products at above	= 2.416	..
Total	<u>= 3.470</u>	..

Theoretical Temperature of combustion = $12000 \div 3.470 + 86^{\circ} \text{F}$
 = 3550° F. = 1960°C.

Similarly:—

Excess air	100%	150%	200%	250%	300%
Temperature	1510°C	1230°C	1040°C	900°C	800°C.

Unburnt Carbon in Ash.—As unburnt carbon in the ash from semi-bituminous steam coals amounts to about 50% of the theoretical ash content of the coal, considering Witbank coal containing 16% ash, 1 lb. of coal when burnt will be reduced to .16 lb. of ash plus .08 lb. of unburnt carbon, and so of the .6645 lb. of carbon in the coal only (.6645 - .08) lb. will be utilized, and the available calorific value will be reduced by (.08 × 14540) = 1160 B.Th.U., and so the available calorific value will be 10860 B.Th.U. per lb. of coal.

To raise the products of combustion of 1 lb. of coal 1° F., allowing for unburnt carbon in ash:—

	Weight	Sp. Ht.	B.Th.U
CO ₂	2.14	.216	.464
H ₂ O ... ..	.39	.475	.185
N ₂	6.12	.244	1.492
Ash ... ..	.16	.200	.032
Unburnt carbon	.08	.212	.017
Total			<u>2.190</u>

Theoretical temperature of combustion = $(10860 \div 2.190) + 86^{\circ} \text{F}$
 = 5040° F = 2760°C

The lbs. of air per lb. of coal for combustion will be 7.96 lbs., and, taking this figure, the temperature of combustion for different percentages of excess air will be:—

Excess air	...	...	50%	100%	150%	200%	250%	300%
Temperature	...	...	1940°C	1490°C	1200°C	1020°C	890°C	800°C.

To show the variation of temperature with excess air I have plotted these figures. (Curve 1.)

One may determine the percentage of air in the flue gases by determining that of the oxygen: the percentage of CO_2 present varies according to that of the excess air, and this determination is the one that is usually made.

The CO_2 from the combustion of 1 lb. of coal (assuming 8% of the carbon unburnt) is 2.14 lbs., at a density of 1.38 relative to oxygen.

Excess air	...	Nil	50%
CO_2 %	...	18.1	11.9

Curve 2 shows these figures plotted, and Curves 1 and 2 are combined in Curve 3 to show the relation between the CO_2 percentage and the theoretical temperature of combustion.

Heat lost in excess air.—Now going on to the consideration of the heat lost in the excess air, assuming the difference between the boiler-house temperature and the stack temperature to be 300° F., for 50% excess air, i.e., 3.98 lbs. of air per lb. of coal, the B.Th.U. lost are:— $(300 \times 3.98 \times 237) = 283$ B.Th.U. Now the available calorific value of the coal (assuming 8% of the weight of the coal of unburnt carbon in the ashes) is 10850, so with 50% excess air the percentage of available combustible wasted will be $(283/10850) \times 100 = 2.6\%$. Curve 4 shows these figures plotted for various percentages of excess air and for various differences in temperature between the stack and the boiler house.

The effect of the ash in coal on its theoretical temperature of combustion.—Comparing with Witbank coal, a coal having approximately the same C/H ratio, and the same percentages of sulphur, etc., but having, say, 10% more ash, the theoretical temperature will be lowered according to the specific heat of the 10% of additional ash, which will be very small. Taking a Witbank coal whose analysis is:—C—66.45; H—4.17; S—1.55; O—8.05; H_2O —1.05; N—1.20; Ash—17.53; and keeping the C/H ratio the same, namely, 15.9, but increasing the ash ratio by 10%, to 27.53, and keeping the remainder the same, we get:—C—57.04%; and H—3.58%. The heat required to raise

Relative volume of $\text{CO}_2 = 2.14/1.38 = 1.54$ units.

The nitrogen from the combustion of 1 lb. of coal = 6.12 lbs. This at a density of .875 gives a relative volume of 7.00 units. The percentage (by volume) of CO_2 is then $(1.54/7.00 + 1.54) \times 100 = 18.1\%$. Taking the air required for the combustion of 1 lb. of coal as 7.96 lbs., and its density relative to oxygen as .90, and working similarly for different percentages of excess air, we get:—

100%	150%	200%	250%	300%
8.7	7.1	5.9	5.0	4.4

the products of combustion 1° F. will be:—

	Weight.	Sp. Ht.	B.Th.U.
H_2O} ...	.33	.475	.157
CO_2 ...	2.09	.216	.452
N_2 ...	5.78	.244	1.412
Ash ...	.27	.200	.054
Total ...			2.070

Now determining the calorific value by the empirical formula:— $1465 \text{ C} + 621 \text{ H} - 54 (\text{O} + \text{N})$, we get a calorific value of 10530, and so the theoretical temperature of combustion is $10530/270 + 86^\circ \text{F.} = \text{approx. } 2860^\circ \text{C.}$ Taking the calorific value of the original coal on the same basis from the formula, we get its calorific value 12280, and a theoretical temperature of combustion of approx. 2860°C. So the addition of 10% of ash has practically no effect on the theoretical temperature of combustion. Apex coal has practically the same C/H ratio as Witbank coal (Apex 15.5, Witbank 15.9), and the remaining constituents are present in about the same percentages, with the exception of the ash, which is about 10% higher; so the temperatures obtainable with Apex and Witbank coals should be practically the same, and in a Dust Fuel boiler this would be the case, but in an ordinary boiler furnace the temperatures obtained with Apex coal are considerably less, the difference being usually about 300°C. and this is chiefly due to the ash hindering, mechanically, the combustion, and the consequent necessity for more excess air.

In practice, apart from the chemical composition of the coal, and the amount of unburnt carbon left in the ashes after com-

bustion, the furnace temperature depends on:—

1. The amount of excess air.
2. The speed of combustion, which can be varied by varying:—
 - (a) The speed of the grate.
 - (b) The thickness of the coal on the grate.
 - (c) The average difference in air pressure between the bottom of the grate and the top of the coal layer: the actual difference in pressure varying with the position on the grate, depending on the shape and size of the arch and combustion chamber, a high arch reducing this difference.
3. The mechanical distribution of the ash and the combustible matter in the coal.
4. The size of the coal.
5. Radiation from the furnace.
6. Conduction by air currents around the boiler, and water currents in the boiler tubes.

Now if the fires are so arranged that combustion is just completed as the ashes drop over the end of the grate, then *for any given grate speed*, if the coal thickness is kept constant, the other items should be practically constant, and so also the furnace temperature, which would represent a definite CO_2 ratio, the ratio of furnace temperature to CO_2 would of course vary with different types of boiler furnaces. In using mixed coals, even though their grade is so arranged so as to complete combustion at the same time, yet the furnace temperature will vary with the ratio in which the coals are used. However, a regular record of the furnace temperatures in a boiler house is useful if one determines for each boiler the amount it is above or below the average temperature for the whole boiler house for the same period; if there is an excessive drop it will indicate that some fault has developed in that particular boiler, and steps can be taken to find out what it is. From the temperature records an estimate can also be formed of the relative work done by individual boilers as a check on the estimate formed by the amount of feed water pumped into the boiler, which latter method sometimes gives confusing results owing to check valves leaking slightly. In one case it was noticed that the average temperature of one boiler was considerably above that in the others, and that it was increasing slightly, this would indicate that this boiler was doing more work

than the others, and so the formation of the scale in the boiler tubes would be quicker, this gradually raising the temperature on the outside of the tubes, and so slightly raising the furnace temperature. The advantage of taking furnace temperatures with an optical pyrometer over CO_2 determinations for estimating relative furnace efficiencies is that one can take readings from all the boilers in a very short time, and so eliminate any factors that affect the boiler house as a whole, such as the changing of the ratio of the coal mixture, and changes in grate speed and draught due to varying loads; whereas making determinations with the Orsat Apparatus would take some hours if one takes two or three readings from each to get average figures. One could, of course, instal automatic CO_2 recorders on each boiler, but this would be expensive and need a lot of attention; however, the use of one CO_2 recorder connected with the main flue is useful in checking the combined efficiency of all the furnaces. Curve 5 shows a record of relative boiler furnace temperatures, being the amount that each boiler is above or below the station average for each week. It will be noticed that generally the furnace temperatures increase slightly, and after a boiler being off for cleaning the temperature is lower, this effect being due to scale forming in the boiler tubes. Number 11 boiler, which has about twice the steaming capacity of the others, and which consequently uses about twice as much air, was off for cleaning during weeks 7 and 8. The draught then distributed itself more evenly between the remainder, and so there was an increase in the average temperatures on the West side, and a decrease in the East side which was most marked on boilers 4 and 5.

The higher the temperature of combustion the higher will be the CO_2 percentage and the furnace efficiency, as shown in Curve 3. The temperature can be raised by increasing the draught, the grate speed, and the thickness of the fires. By increasing the draught about $1\frac{1}{2}$ " or 2" water gauge, the boilers need much more attention to avoid air leakage, and the expense of this may counteract the saving in coal. Also, if too high furnace temperatures are used, the life of the grate links is much reduced. In practice a medium temperature is preferred to reduce expenses in attention and renewals. The Dust Fuel boiler again has the advantage here, as the combustion chamber can be made entirely of refractory material, and so the expenses in upkeep will not increase materially by using

high temperatures. Temperature/ CO_2 figures obtained from a Babcock boiler have been plotted on Curve 3, the variations in temperature being due to variations in grate speed and draught to suit the changing loads. The difference between this curve and the theoretical curve is due to the type of coal used, to conduction and to radiation (varying according to Stefan's Law); both of these latter varying with the design of the boiler.

The different temperatures in different parts of a boiler furnace follow, more or less, the following typical examples:—

1' from the hopper	980°C. to 1070°C.
1' 6" from the hopper	1020°C. to 1070°C.
8' 6" from the hopper	1020°C. to 1070°C.
10' from the hopper	970°C. to 1060°C.
The end of the bright flame, the position of which will vary according to the grate speed, etc.	880°C. to 1040°C.
Ashes going over end of grate	840°C. to 880°C.

As the coal travels along with the grate it becomes smaller in volume owing to the loss of its combustibles, and so the draught can get through it more easily, this increased air being used for the combustion of the small remaining portion of combustible matter, thus the percentage of excess air increases towards the back of the boiler, and results in a lower temperature. In this connection, if experiments in producing water gas from the carbon in the ashes on the tippler prove successful it would be of advantage to arrange for the ashes to drop off the end of the grate in a less completely burned state, so as to reduce the percentage of excess air coming through the back of the grate. In most modern boilers there is a device for limiting the amount of air supplied to the back portion of the fire; this in chain-grate stokers usually taking the form of vanes under the grate at the back, and in under-feed stokers of a separate air flue for the back, controlled by a damper.

The determination of furnace efficiencies by temperature readings is most accurate in a dust-tuel boiler, as with that the temperature is more uniform throughout, as with gas combustion.

Mixing Coals.—If one can obtain a cheap low grade coal it is often economical to use it, even if one has to mix with it a certain amount of better coal to increase the calorific value; and apart from economy, the mixing of high and medium grade coals with low

grade coals is of great advantage in a steaming station that has to cope with big variations of load, such as is the case on the Rand mines, where, during the underground shift the load is much greater than during the rest of the day; these variations can be coped with in the boiler house by increasing or reducing the ratio of the better coal, and of course adjusting the draught and the grate speed accordingly. In mixing coals their relative sizes should be so arranged that they complete combustion in the same length of time; thus a quick burning coal should be larger in size than a slow burning one, such as when Apex and Witbank coals are mixed, the Apex coal should be slightly larger in size than the Witbank. In mixing coals care should be taken that they are mixed well, and this is usually arranged by having a conveyor belt system under the coal bins, and arranging for the coal to be fed on to the belt simultaneously from the different bins. If they are not mixed well the fires will show dark streaks which reduce their efficiency; and if, for example, there is a pocket of duff coal, this will go over the grate without getting properly burned, and it will lower the furnace temperature and so affect the combustion of the coal around it. Coal containing much duff is a disadvantage, especially in a station where the draught is low, as it fills in the spaces between the coal pieces and there cakes and prevents the air from coming through. If in a station where the draught averages .5" water gauge, the duff percentage comes to over 15%, it would be economy to screen it out and throw it away, or if no screening plant is available and the duff is more than 20%, it would be economy to discard the whole truck load of coal, as is shown by station records. Then in mixing coals there is the consideration of the ash; if this is too fusible, so that there is difficulty for the air to get at the carbon, the addition of a coal having a more infusible ash is an advantage, as this renders the whole less fusible; the effects of the constituents in this respect is shown later.

Storage.—In 1909 Mahler proved that when air is passed over dry coal, free from occluded gas, at as low temperatures as 25°C. to 30°C., water, CO_2 and CO are formed, thus showing that as soon as air comes into contact with coal, oxidation commences, and so coal gradually loses its heat value on storage. If coal is used that has been lying at the sides of the bunkers for a month or so the increase in the coal consumption is noticeable. This should be taken

into consideration in designing bunkers, which should be so arranged that the oldest coal will be removed first. In addition to the loss of calorific value, coal on lengthy storage breaks up into smaller pieces and duff, which further greatly destroys its usefulness, and this action is accelerated if the coal bins are open to the weather: in fact, if coal has been lying exposed to the extremes of the weather for several months it becomes practically useless. If, however, it is stacked in large stacks this action is largely kept to the surface layer; but then there is always the possibility of spontaneous combustion, and as a protection against this it is an advantage to place thermo-couples in various positions throughout the stack, so that one can determine any serious rise in temperature and take steps to stop it.

Spontaneous Combustion.—From Mahler's researches we see that oxidation of coal takes place at ordinary atmospheric temperatures, and this would apply particularly to coals high in volatile matter. If the coal is not in a confined space the action will not be cumulative; if, however, the conduction away of the heat generated is restricted the temperature will increase, and the oxidation will become quicker, until finally the coal will ignite. Thus the grade of the coal is an important factor, for if it is large and irregularly shaped the exposed surfaces and the surfaces in contact are small, so the heat can be readily conducted away; but if there is much small coal and duff present, even if only the surfaces of the coal are covered with duff, then heat conduction is hindered, and so the cumulative action is increased. When pyrites are present in a finely divided state, especially in the presence of moisture, oxidation of that takes place and so increases the effect. Microphotograph 18 shows the development of ferric sulphate by the oxidation of fibrous pyrites from Apex coal. This action takes place even when coal is stored under the most favourable conditions, for samples of pyrites kept in a reasonably dry room for some months showed distinct signs of sulphating. The presence of occluded gas in coal must also have some effect in accelerating spontaneous combustion, as it contains free hydrocarbons and oxygen. From a paper read by Mr. James Lomax before the Institute of Mining Engineers I gather that certain coals, no matter in what size or condition, are liable to spontaneous combustion, and these are not always those with the highest percentage of volatile matter or pyrites,

but they have certain characteristic arrangements of the constituents by which they can be identified under the microscope.

The Microscopic Examination of Coal.—To prepare microscopic slides of coal for examination by transmitted light is, even with the use of cements and gums, a very delicate and tedious process, so I have developed a method for the preparation of specimens for reflected light, similar to the preparation of metallographical specimens, by polishing and etching or heat tinting suitably to bring out the desired characteristics, such as the distribution of the incombustible matter, the fixed carbon, and the volatile matter, as shown in Microphotographs 9, 10, 11, and 12, from which one can estimate the suitability of coals for different purposes.

The Choice of Coal for Steaming.—To a great extent the choice of a coal for steaming, and the design of the boiler furnace in which it is to be used, depend on one another. The higher the percentage of volatile matter in the coal the larger must be the combustion chamber. If this is too small the gases will not be completely burned when they reach the boiler tubes, the cooling from which will prevent their further combustion, and apart from the loss in furnace efficiency when this effect is excessive it will lead to soot being formed around the boiler tubes and so necessitate frequent cleaning. A coal very high in volatile matter, say, above 35%, will require for complete combustion a combustion chamber whose size will render it costly in erection and maintenance, and its large external surface will mean a correspondingly large loss through radiation and conduction.

A coal very low in volatile matter will burn with a very low intense flame, such as with anthracites, and this will mean excessive heating of the grate links with attendant high upkeep expenses. The speed of combustion also will be slower, and this will particularly be the case with the Natal anthracites, where the ash percentage is fairly high (12% to 15% against the Welsh anthracites containing 4% to 5% of ash, and often less).

Thus the most suitable coal for steaming purposes are those coming between these two, namely the semi-bituminous.

Then there is the consideration of the resulting ash, which should break up readily to allow the combustion of the carbon to take place. Coals having their incombustible

matter distributed as that in Microphotographs 11 and 12 are suitable in this respect, as on combustion they become cellular (v. Microphotograph 14) and then break up into powder. When the incombustible matter is distributed as in Microphotographs 9 and 10, the combustion cannot be so complete, as the ash retains, more or less, its original shape, and prevents the air from getting at the interior. In semi-bituminous coals one gets bands of both of these types, and one then has to form an idea of the suitability of the coal as regards the mechanical distribution of the constituents, by estimating the ratio in which these two types are present.

Another point to be considered in the choice of a coal is that of the ash, forming slag and so clinkering. With furnace temperatures under 1100°C ., the slag chiefly consists of the bisilicate of iron, which has

a melting point of 1065°C .; but at higher temperatures the slag includes more of the bisilicates of calcium and aluminium, whose melting points are about 1400°C ., but which when mixed with iron bisilicate will have lower melting points depending on the proportions in which they are present. With furnace temperatures less than 1000°C . there is little slag formed, though there is often enough, due to local higher temperatures immediately around the coal, to fuse the coal pieces together and so form an open clinker.

The bi-silicates usually have the lowest melting points of the silicate slags, and so it is they that are usually formed. Their compositions are:— $2\text{FeO}.\text{SiO}_2$, $\text{CaO}.\text{SiO}_2$ and $\text{Al}_2\text{O}_3.3\text{SiO}_2$. The slag calculations for an ash will be as follows, the amount in which the actions are completed depending on the furnace temperature:—

2 FeS_2 becoming 2 FeO requires for slag formation ...	SiO_2 .	<u>Silica.</u>
2 (56 + 64)	28 + 32	
1 lb. of FeS_2	60.240 =	<u>.25lb.</u>
CaCO_3 becoming CaO requires for slag formation ...	SiO_2 .	
(40 + 12 + 48)	28 + 32	
1 lb. of CaCO_3	60.100 =	<u>.6 lb.</u>
Al_2O_3 requires for slag formation ...	3 SiO_2 .	
54 + 48	3 (28 + 32)	
1 lb. of Al_2O_3	180/102 =	<u>1.76 lb.</u>

Slag, forming clinker, is a serious disadvantage in boiler furnaces, as besides clogging up the spaces between the fire-bars it prevents combustion of the coal as shown in Microphotograph 15; so in choosing coals those producing the least clinker are the most desirable, and as, at ordinary temperatures, the chief slag forming content of coal is the pyrites, it would be of advantage to the consumer when purchasing coal to stipulate a maximum pyritic content, and if supplied above this percentage a rebate should be arranged for.

Notes on Overall Boiler House Efficiencies.—In a station generating 35,000,000 lbs. of steam per month at 160 lbs./sq in., it was found that the lbs. of coal per lb. of steam was as much as .23, with a coal averaging 10500 B.Th.U. per lb. of coal and 15.7 C/H ratio. The load was distributed over a bank of 10 Heine boilers and 1 Babcock boiler, the latter being equivalent in steaming capacity to about three of the former, as is shown later. Now assuming one Heine boiler to be always off for cleaning, the load per Heine boiler per month

would be 35,000,000/12 lbs. of steam = 2,900,000 lbs. of steam; and the coal per Heine boiler would be (2,900,000 \times .23) lbs. = 667,000 lbs. per month = 667,000/43,200 lbs. per min. = 15.5 lbs./min., for which a combustion space of about 110 c. ft. was available. To increase the furnace efficiency this combustion space was increased to about 330 c. ft., by lowering the grates 2 ft., and the effect of the alterations on the boiler house efficiency is shown in Curve 6; and in Curve 7 is shown the rate of improvement per boiler altered. Considering Curve 7 it will be noticed that up till the 3rd altered boiler the reduction in lbs. of coal per lb. of steam per boiler altered, decreases at the rate of .006 lbs. per altered boiler; and after this, up till the 8th boiler, the reduction per boiler is constant; and, after the 8th boiler, there is no reduction. This shows that originally the boilers were overloaded, and so working uneconomically, but as each altered boiler was put into commission the steaming capacity of the station was increased by 50% of one Heine boiler, as is shown later, and after the third altered

boiler was put into commission, the station capacity was so increased that none of the boilers were being overloaded. Only eight boilers were altered, as these can efficiently cope with the station load, allowing for two being off at a time for cleaning; so after the 8th the reduction in lbs. of coal per lb. of steam would be nil.

That the increase in the steaming capacity of a Heine boiler was increased by 50% by the alterations, is computed as follows:—

Normally the load is taken by 1 Babcock boiler and 6 altered Heine boilers; and when the Babcock boiler is off for cleaning the load is taken by 8 altered Heine boilers. Before the alterations this load was taken by 1 Babcock boiler and 9 unaltered Heine boilers; so taking:—

$B = 1$ Babcock boiler $= 2$ altered Heine boilers (since 2 altered Heine boilers were put on to replace the Babcock when off for cleaning).

$h' = 1$ altered Heine boiler, and $h = 1$ unaltered Heine boiler.

Then $9h + B = 6h' + B$

$$9h = 6h'$$

$$h' = 9/6 h = 1\frac{1}{2}h.$$

Thus, by the alterations, the capacity of the Heine boiler is increased by 50%.

From these figures we get the efficient load per boiler thus:—

$3h' = 35,000,000$ lbs. of steam per month.

$h' = 4,375,000$ lbs. of steam per month.

$= 6,100$ lbs. of steam per hour.

Thus 1 altered Heine boiler evaporates effi-

ciently 6,000 lbs. of steam per hour at 160 lbs./sq. in., and the Babcock 12,000 lbs. under the same conditions.

TABLE I.

L = Side of cube in inches.

b = Ratio of area exposed to volume = $6L^2/L^3 = 6/L$.

L .	b .
6.0	1.0
5.0	1.2
4.0	1.5
3.5	1.7
3.0	2.0
2.5	2.4
2.0	3.0
1.5	4.0
1.0	6.0
.9	6.7
.8	7.5
.7	8.6
.6	10.0
.5	12.0
.4	15.0
.3	20.0
.2	30.0
.1	60.0
.09	66.7
.08	75.0
.07	85.8
.06	100.0
.05	120.0
.04	150.0
.03	200.0
.02	300.0
.01	600.0

REFERENCE TO MICROPHOTOGRAPHS

1. x 35
Carbonised remains of Conifer Wood from Apex Coal

2. x 700
Splinter from carbonised Conifer Wood from Apex Coal showing the typical bordered pits (The author is indebted to Miss P. Rolland, B.A., for her assistance in identifying this)

3. x 35
Petrified wood from Apex Coal showing annual rings. Transverse Section

4. x 350
Petrified wood from Apex Coal, showing skeletons of Microbes. Transverse Section

5. x 800
Skeletons of Microbes from petrified wood in Apex Coal, showing elongation, fusion and colonies of Microbes

6. x 150
Portion of C.I. grate link, after having been heated in contact with pyrites, showing the derived ferrous sulphide between the crystal grains.

7. x 15
Distribution of Lame in portions of Apex Coal

8. x 35
Fibrous Pyrites from Apex Coal, having been deposited in Conifer Wood (cf. Microphoto. 1)

9. x 35
Dull portion of Apex Coal, showing distribution of incombustible matter, fixed carbon and volatile matter.

10. x 35
Dull portion of Twententem Coal, showing distribution of incombustible matter, fixed carbon and volatile matter.

11. x 35
Banded portion of St. George's Coal, showing distribution of incombustible matter, fixed carbon and volatile matter.

12. 7 1200
Portion of the same specimen shown in Microphotograph 11, more highly magnified.

13. x 35
Banded coal, after having been heated slightly, showing the cracking between the layers.

14. x 35
The same specimen as shown in Microphotograph 13, but broken between the layers, and viewed at right angles to the bedding plane.

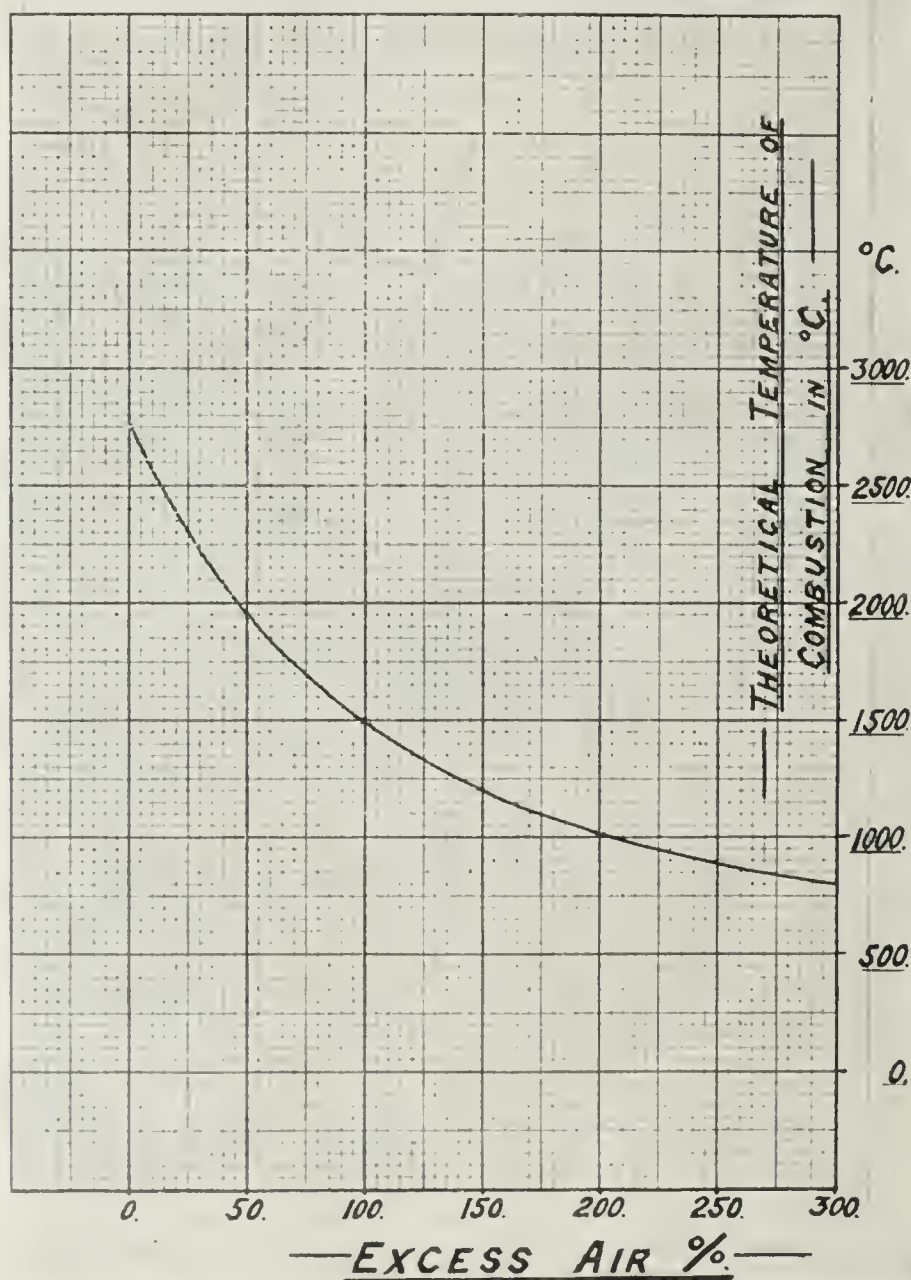
15. x 17
Dull portion of Apex Coal, after being burned, showing the effect of infusible ash in preventing complete combustion.

16. x 150
Boundary between completely burned ash and that containing some carbon, in specimen shown in Microphotograph 15.

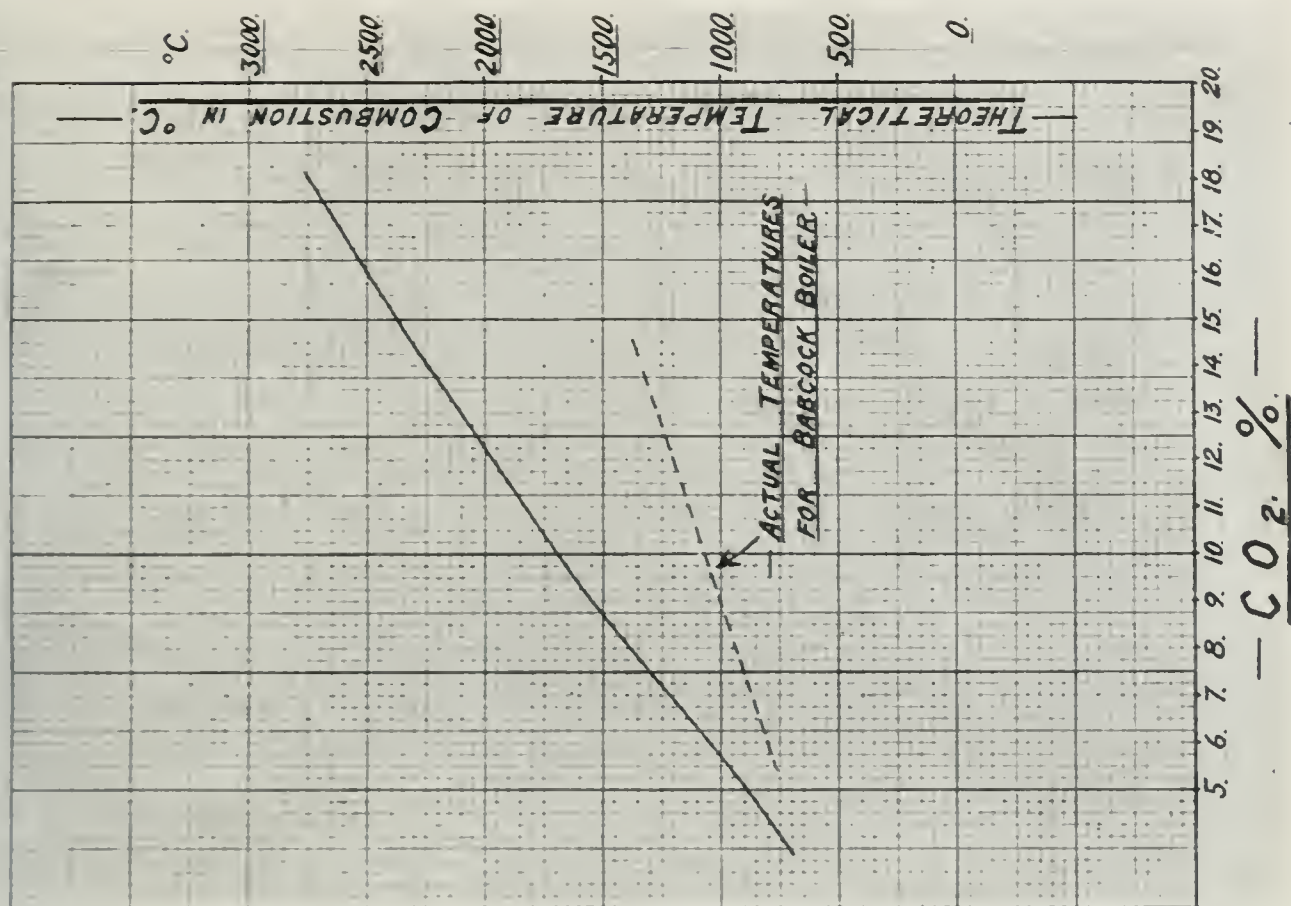
17. x 35
Ash, showing the effect of slag in preventing oxidation.

18. x 35
Fibrous pyrites from Apex Coal, showing the development of ferric sulphate on exposure.

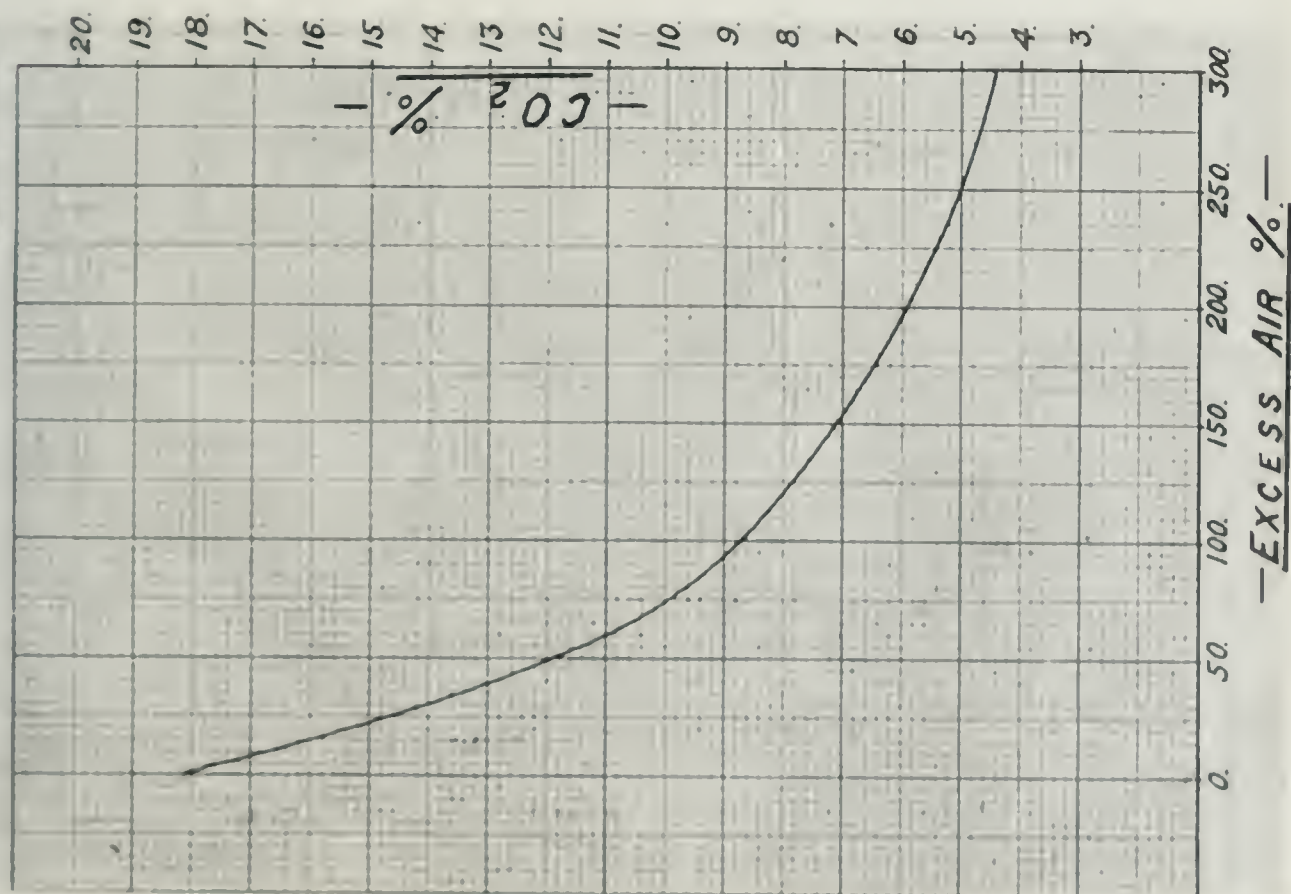
CURVE 1.



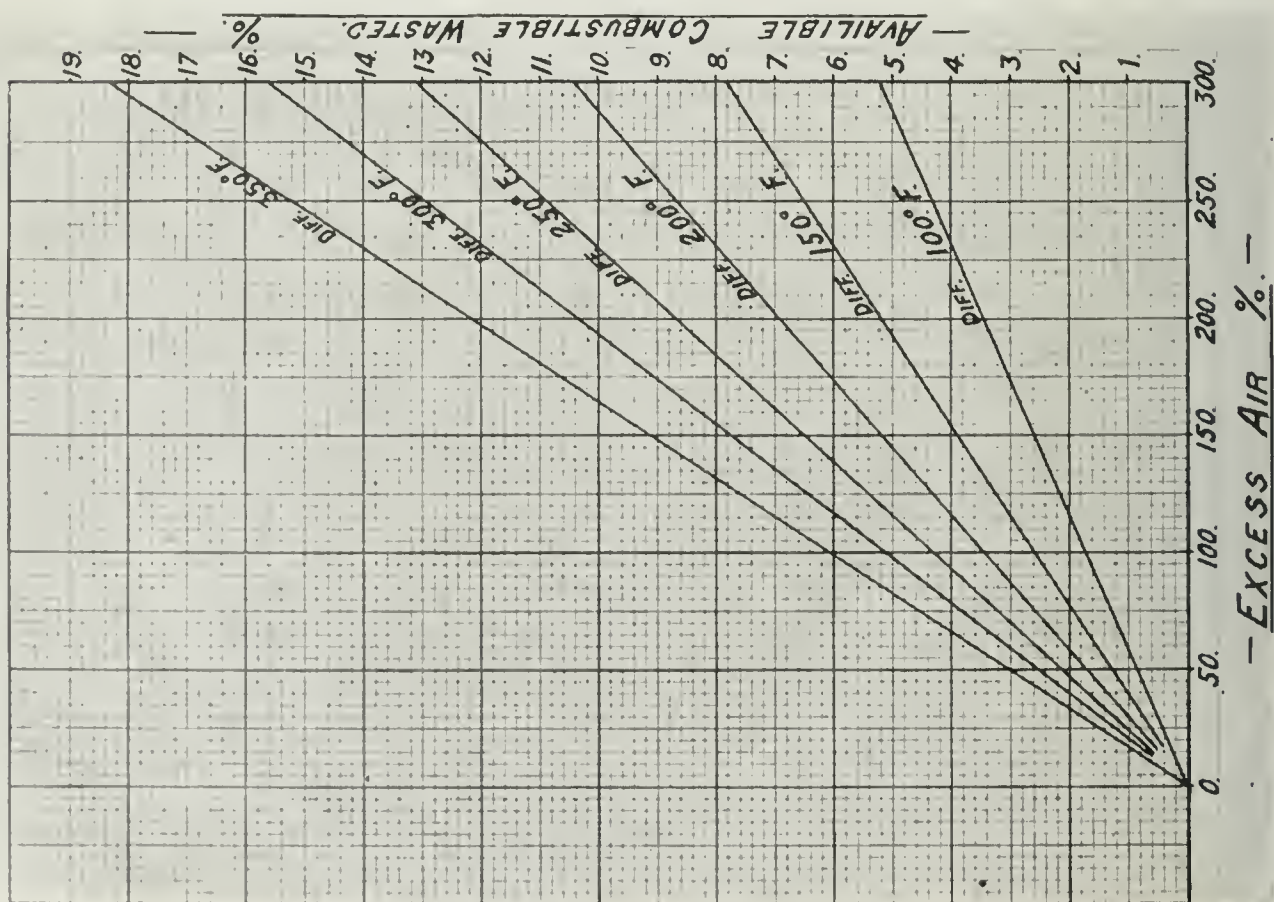
CURVE 3



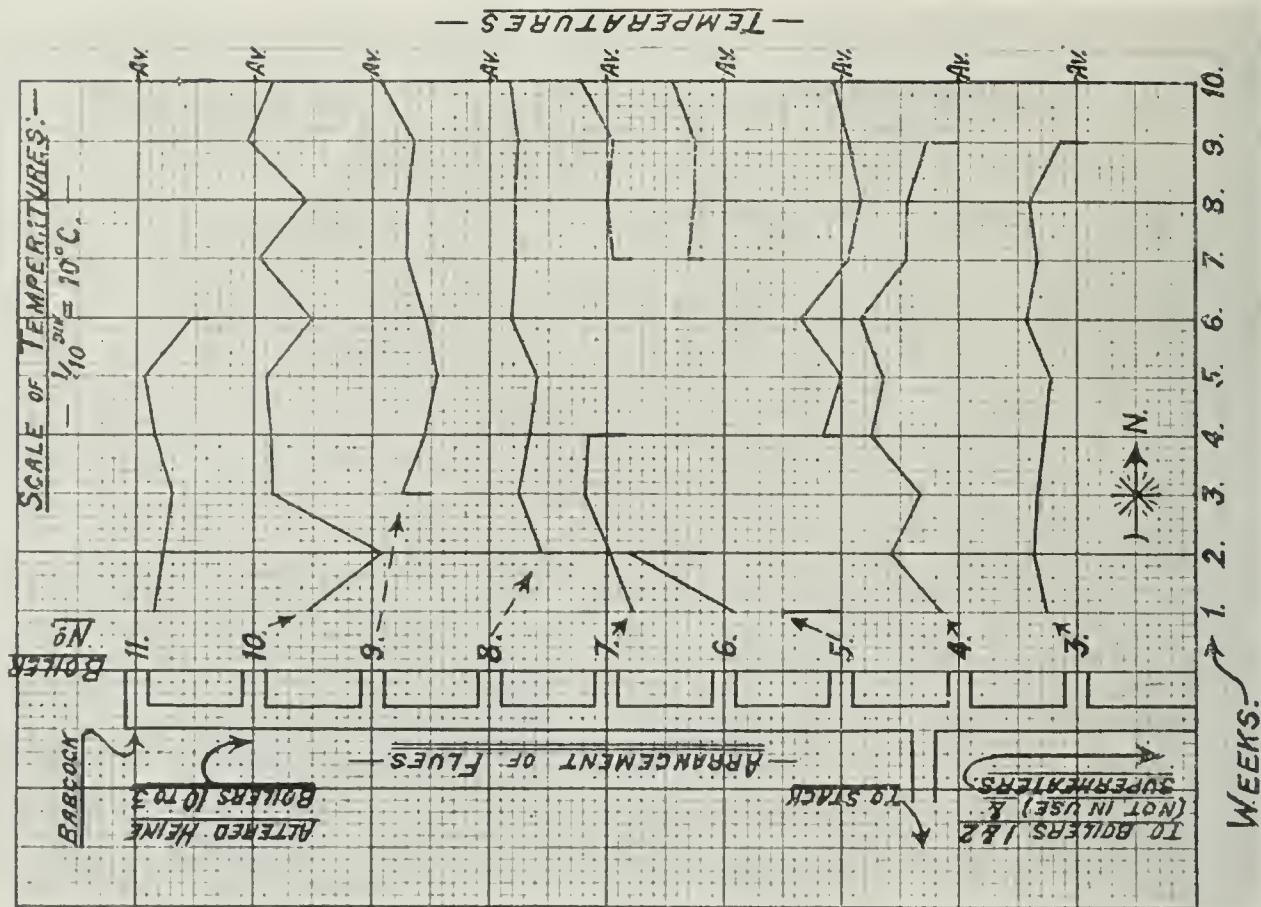
CURVE 2



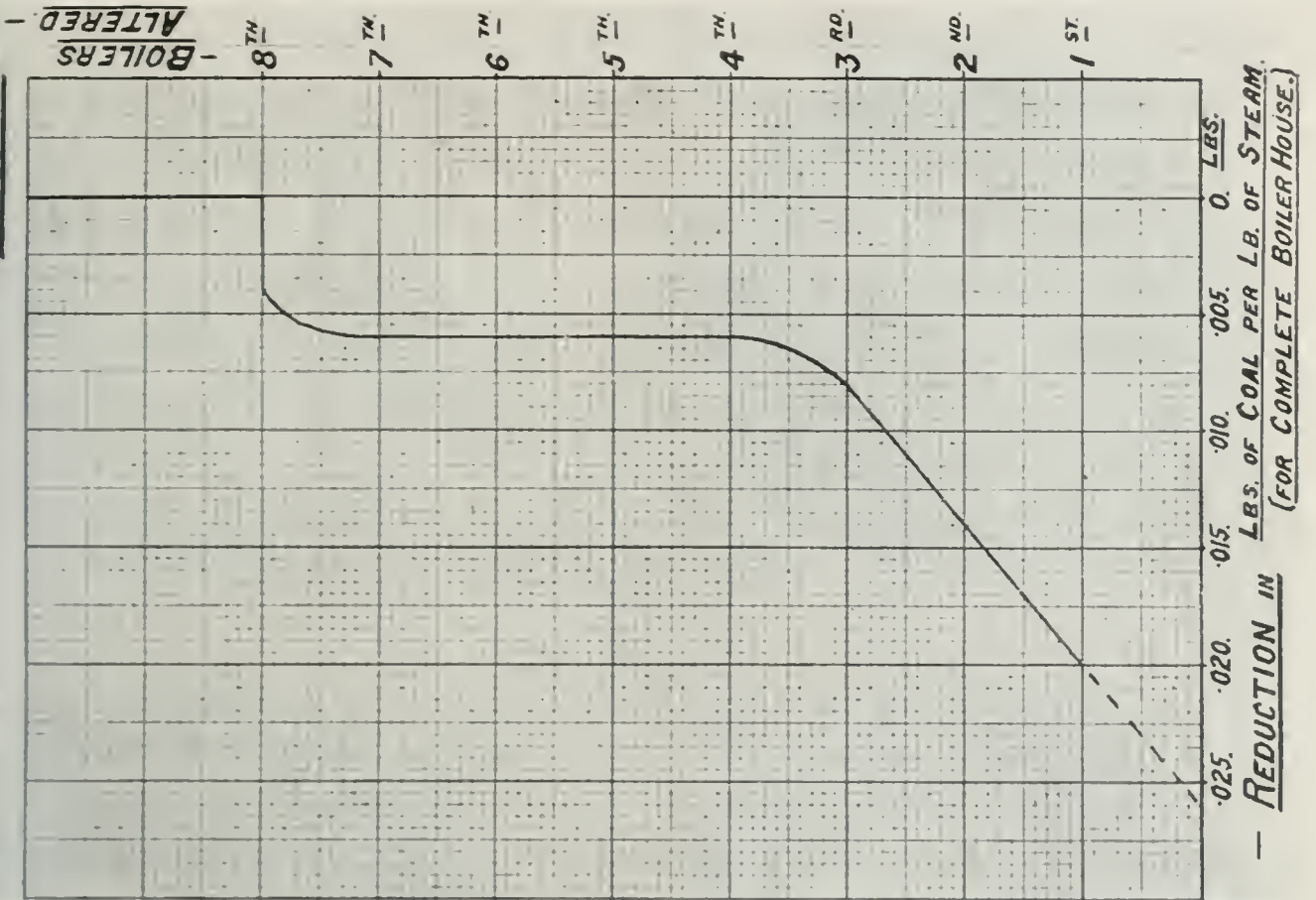
CURVE 4.



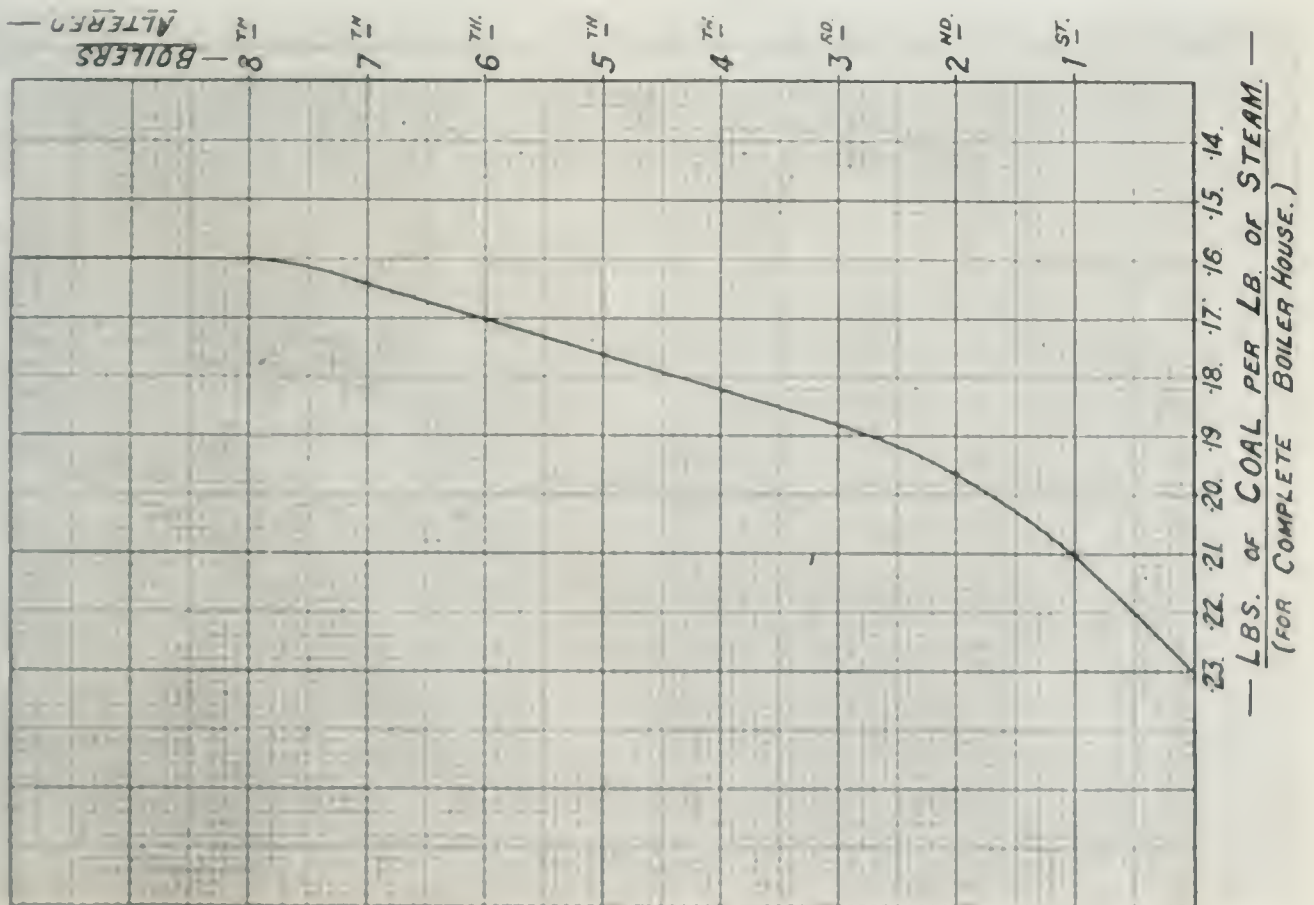
CURVE 5.

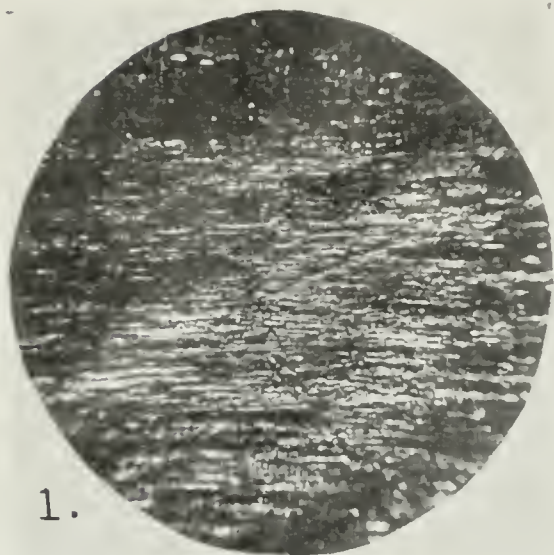


CURVE 7.



CURVE 6.



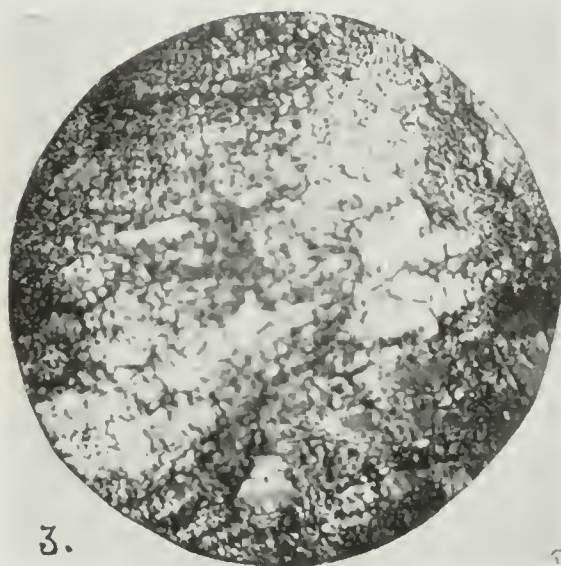


1.

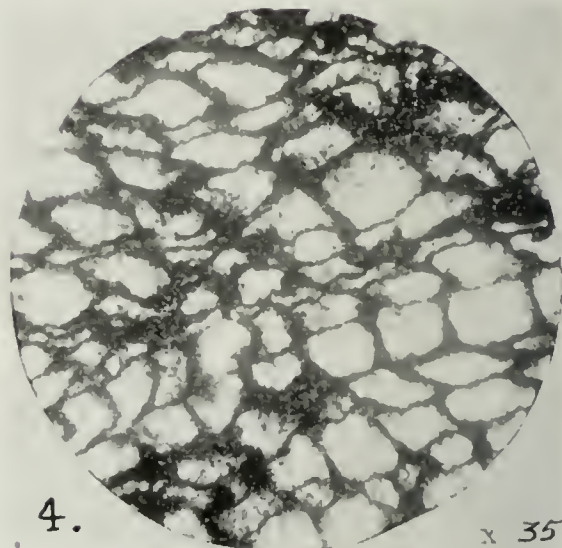


2.

x 700

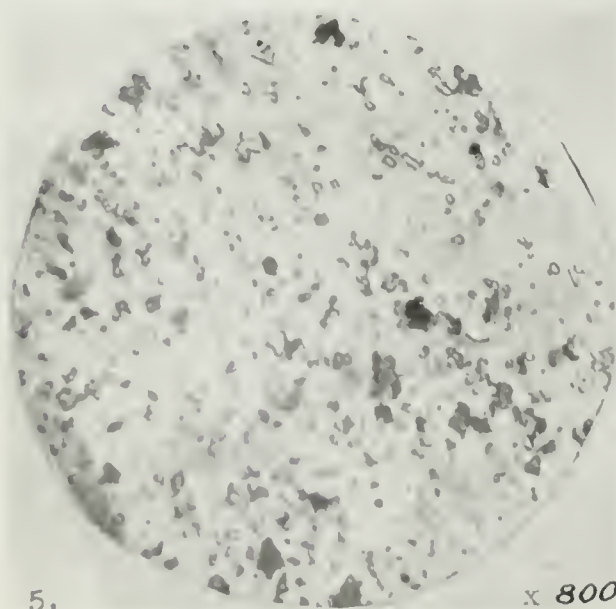


3.



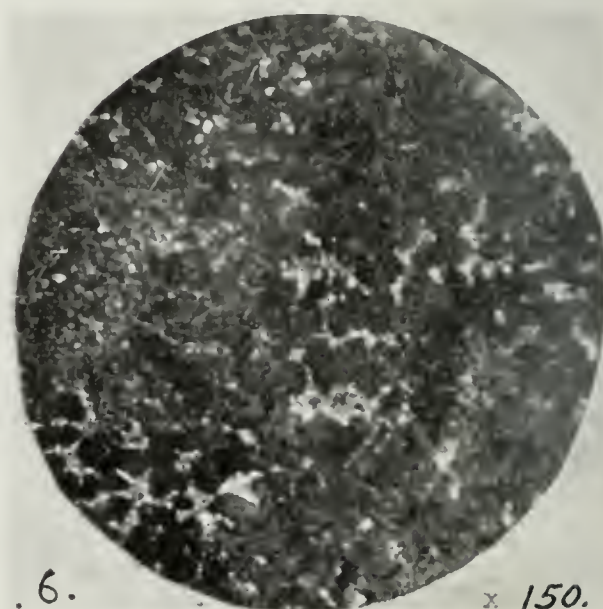
4.

x 350



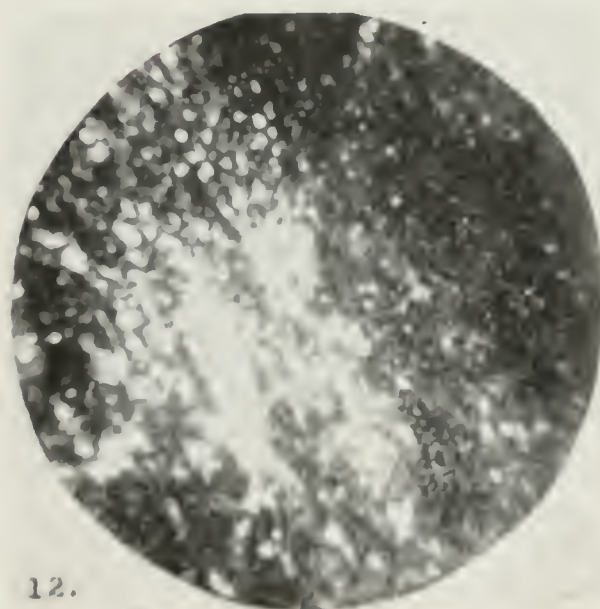
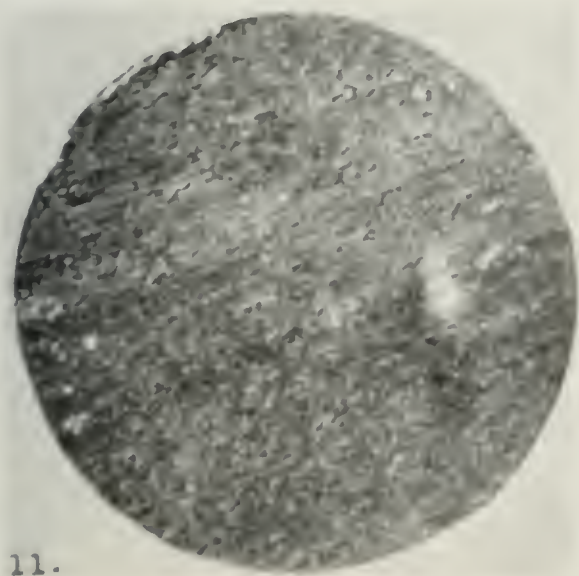
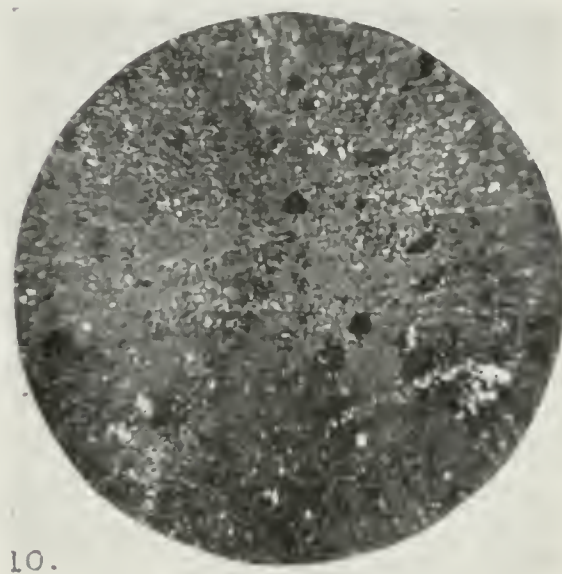
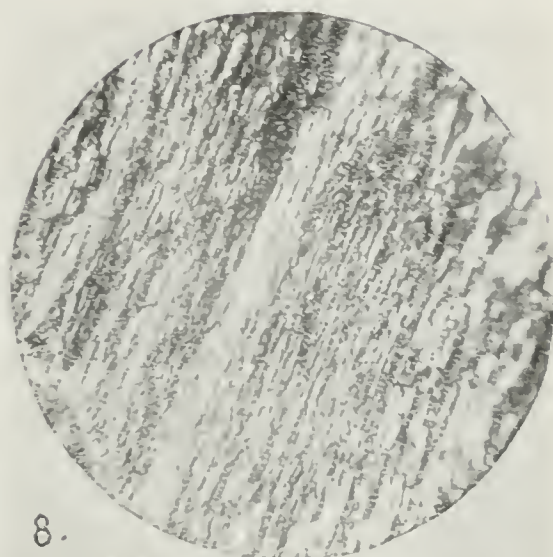
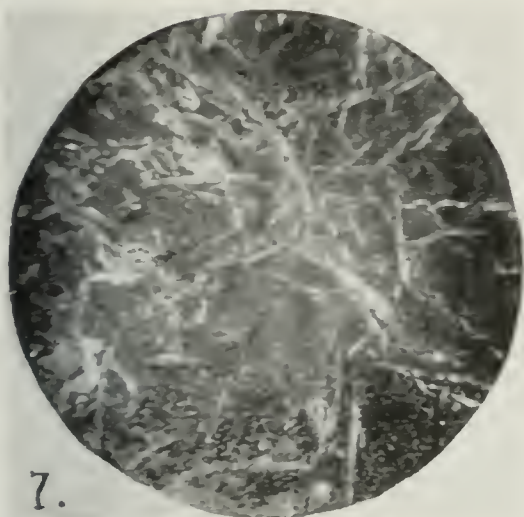
5.

x 800



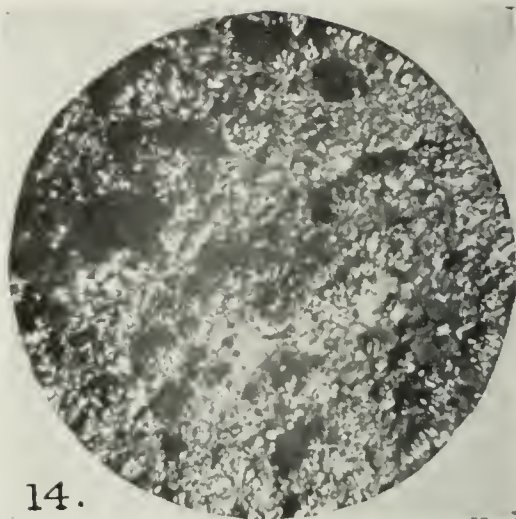
6.

x 150.

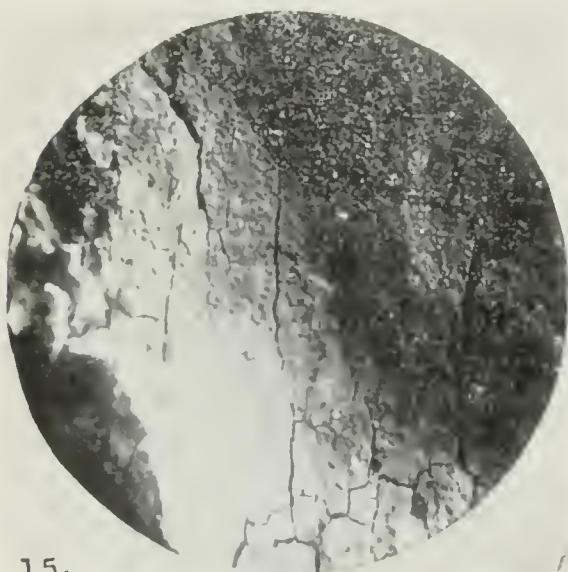




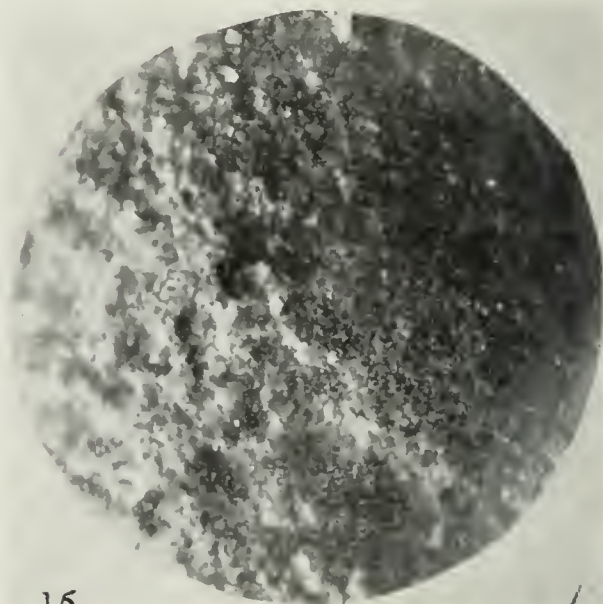
13.



14.



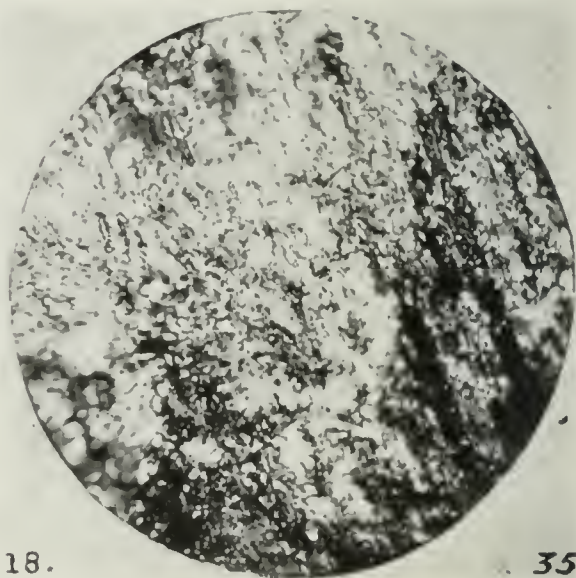
15.



16.



17.



18.

MINE AMBULANCE COMPETITIONS.

These competitions were inaugurated by the Chemical, Metallurgical and Mining Society of South Africa in 1912, when the Society offered for annual competition two shields, one for underground workers and one for surface workers on the metalliferous mines of South Africa.

The shields are competed for by ambulance teams of five men, one team being allowed for each hundred (or portion thereof) white men employed on any one mine. A silver medal is also presented to the winning team and a bronze medal to the second team each year.

In 1915 the control of the competition was taken over by the South African Red Cross Society, which now provides the silver and bronze medals.

The following are the winning teams in the metalliferous mines competitions since their inception:—

SURFACE WORKERS' SHIELD.

1912—Limpaardsvlei Estate and G.M. Co., Ltd.

1913—Limpaardsvlei Estate and G.M. Co., Ltd.

1915—Crown Mines, Ltd.

1916—Crown Mines, Ltd.

1917—Village Deep, Ltd.

1918—Village Deep, Ltd.

1919—Limpaardsvlei Estate and G.M. Co., Ltd.

1920—Village Deep, Ltd.

1921—New Kleinfontein Co., Ltd.

UNDERGROUND WORKERS' SHIELD.

1912—West Rand Consolidated Mines, Ltd.

1913—Limpaardsvlei Estate and G.M. Co., Ltd.

1915—Crown Mines, Ltd.

1916—Crown Mines, Ltd.

1917—Village Deep, Ltd.

1918—Crown Mines, Ltd.

1919—Crown Mines, Ltd.

1920—Crown Mines, Ltd.

1921—East Rand Proprietary Mines, Ltd.

VISIT TO THE SOUTH AFRICAN INSTITUTE FOR MEDICAL RESEARCH, JOHANNESBURG.

On the invitation of Dr. W. Watkins Pitchford, Director of the South African Institute for Medical Research, on Saturday, 2nd December last, members of the Society visited the Institute which is supported by the Government and the Transvaal Chamber

of Mines. A highly instructive morning was spent in a tour through the section devoted to the examination of men coming under the Phthisis Act and through the bacteriological and medical laboratories. In these comprehensive work is carried on and is divided into sections dealing with the examination and study of foods, bacteriological examination and diagnosis for hospitals and the medical profession throughout South Africa, the production of serums and vaccines, and research into causes and prevention of diseases peculiar to this country.

The work of the Institute was explained in short, illustrated lectures by the Director and by the heads of different sections, Dr. W. Watkins Pitchford, Dr. J. Harvey Pirie, Dr. A. Mavrogordato, Dr. Annie Porter, and Dr. B. D. Pullinger.

Dr. Watkins-Pitchford stated that in regard to silicosis a clearer conception now existed; it could be recognised definitely. The rigid examination of all recruits for underground service had resulted in a marked rise in the health of underground workers and the annual contribution of the mines to the Phthisis Fund had been greatly reduced.

The President, on behalf of the members of the Society, expressed appreciation and sincere thanks to the Director and the Staff of the Institute for the interesting visit.

To those who were able to join the visiting party, he stated, the visit had given an insight into the complex scientific organisation necessary to provide a country like South Africa with medical safeguards considered necessary for our state of civilisation. The institution was a fortification against epidemics and held in check the continual onslaught of microbes, a number of which had been exhibited that morning. The Chemical, Metallurgical, and Mining Society had always taken a keen interest in industrial health conditions, and Dr. Mavrogordato's summary of his activities in the field touched a sympathetic cord. The subjects in which Dr. Pullinger and Dr. Annie Porter were specialising, vitamins and food investigations, we had dealt with in the columns of our Journal, and were therefore interested. Dr. Pirie's lecture on methods employed in bacteriological work had cleared some of the mist enveloping members in the past. It might be said that they were deeply impressed not only with the facilities for research and the research actually in progress, but also with the human value of the routine work and with the fact that in

these commercial days men and women were found who devoted their lives to Scientific investigation largely for the love of science. The South African Institute of Medical Research was worthy of support by all citizens of the country and worthy of endowment especially by those who had acquired their wealth out of its natural resources.

Notices and Abstracts of Articles and Papers.

CHEMISTRY

THE COLORIMETRIC METHOD OF DETERMINING HYDROGEN ION CONCENTRATION: SOME APPLICATIONS IN THE ANALYTICAL LABORATORY.—Hitherto in the literature of analytical chemistry the terms "acidity" and "alkalinity" have in general been very loosely employed. "Acidity" or "alkalinity" have usually been determined by titration and expressed in one of two ways: (a) as the number of c.c. of standard acid or alkali required by a given weight of the substance in order to render it neutral to some indicator; (b) as the percentage of some acid or alkali to which the acidity or alkalinity is ascribed, in some cases quite arbitrarily. If we require to find the percentage of a single acid or alkali which we know to be present, there is no objection to the titration method, but in many cases the important point is not the total percentage of acid or alkali present, but the number of hydrogen or hydroxyl ions present.

Hydrogen ion concentration rather than the amount of acid present is the important factor in the curdling of milk, the precipitation of proteins, the hydrolysis of sugars, and processes of digestion or fermentation, to take only a few instances. The majority of bacteria, yeasts, etc., have a range of hydrogen ion concentration at which their growth is at a maximum, and for this reason this factor is of the greatest importance in the case of bacteriological media and in biological processes generally.

The complete precipitation of metals as their sulphides in inorganic analysis is dependent on the hydrogen ion concentration of the solution, as is also the corrosion of metals by mine water. If "acidity" or "alkalinity" were expressed in terms of the hydrogen ion concentration of a solution of known strength this would merely involve the use of a number without reference to any particular indicator, acid or alkali.

Owing to the work carried out in recent years the accurate determination of hydrogen ion concentration is now a comparatively simple matter. If only reasonable accuracy is required determinations can be carried out as a routine test in any laboratory not involving any special apparatus or skill.

Method of Expressing Hydrogen Ion Concentration.—Dr. Monier Williams (*Analyst*, 1921, 345), has dealt with the theoretical considerations involved. The symbol P_{H} , or p_{H} , by which hydrogen ion concentration is expressed,

indicates the logarithm of the reciprocal of the concentration of hydrogen ions in terms of normal—e.g., $P_{\text{H}}=2$, the hydrogen ion concentration is $N \times 10^{-2}$, or one-hundredth normal; when $P_{\text{H}}=3$, one thousandth normal, and so on. At the point of absolute neutrality, i.e., for pure water— $P_{\text{H}}=7$. When P_{H} is less than 7 the liquid is acid, and when P_{H} is greater than 7 the liquid is alkaline.

The Colorimetric or Indicator Method.—This method, though sufficiently accurate for ordinary purposes, is not capable of as great accuracy as the electrometric method. It requires, however, no special apparatus, and a large number of determinations can be carried out at the same time. It is inapplicable to very dark solutions, though it may be used for coloured solutions if the colour is not too deep. It may be used with success with turbid liquids such as milk.

The colorimetric method depends on the fact that with every indicator the colour change extends over a characteristic zone of hydrogen ion concentration, the total change of colour occurring inside a range of about 18 units of P_{H} ; if, therefore, the hydrogen ion concentration of an unknown liquid lies within the range of a certain indicator, we can determine the factor with accuracy if we can find a solution of known hydrogen ion concentration which gives the same shade of colour with the indicator. The two essentials for this method are, therefore: (a) A complete series of indicators with well-marked colour changes which will cover a wide range of hydrogen ion concentration; (b) solutions of known hydrogen ion concentration which are easily prepared and stable. By the use of some of the recently synthesised indicators of the phthalein series, together with methyl red, we can fulfil the first requirement. As the accompanying chart shows, these indicators show brilliant and permanent colour changes over a range of $P_{\text{H}}=1$ to $P_{\text{H}}=11$. If we have a solution of unknown hydrogen ion concentration, and we test it with various indicators until one is found to give a shade of colour intermediate between its extreme shades, we can then find a solution of known hydrogen ion concentration which gives the same shade of colour with the same amount of indicator.

Solutions of Known Hydrogen Ion Concentration.—It is not possible for this purpose to use solutions of acids or alkali of known strength on account of the susceptibility of such solutions to changes of hydrogen ion concentration from accidental causes, such as the alkalinity of the glass, etc., but this difficulty may be overcome by introducing certain salts, such as phosphates, borates, etc., which have a "buffer" action, i.e., which have the property, when in solution, of causing the hydrogen ion concentration to be only slightly affected by the addition of moderate amounts of acids or alkali. For ordinary purposes the following four solutions, together with $\frac{N}{10}$ hydrochloric acid and $\frac{N}{10}$ sodium hydroxide, are all that are required. By taking definite volumes of any of these solutions, with different volumes of $\frac{N}{10}$ hydrochloric acid or $\frac{N}{10}$ sodium hydroxide, solutions of practically any P_{H} required may be obtained.

1. Standard (M/15) potassium dihydrogen phosphate solution is prepared by dissolving 9.078 grms. pure potassium dihydrogen phosphate (KH_2PO_4) in 1,000 c.c. water.

2. Standard (M/15) sodium phosphate solution is prepared by dissolving 23.87 grms. pure sodium phosphate ($\text{Na}_2\text{HPO}_4 \cdot 12\text{H}_2\text{O}$) in 1,000 c.c. water. All effloresced crystals, which do not contain $12\text{H}_2\text{O}$, must be picked out.

The last two solutions are used in combination.

Phosphate Standards.

M/15 Na_2HPO_4	M/15 KH_2PO_4 Solution.	P_H
C.c.	C.c.	
0.0	10.0	4.49
0.1	9.9	4.91
0.25	9.75	5.29
0.5	9.5	5.59
1.0	9.0	5.91
2.0	8.0	6.24
3.0	7.0	6.47
4.0	6.0	6.64
5.0	5.0	6.81
6.0	4.0	6.98
7.0	3.0	7.17
8.0	2.0	7.38
9.0	1.0	7.73
9.5	0.5	8.04
9.75	0.25	8.34
9.9	0.1	8.68
10.0	0.0	9.18

The following solutions are required:—

$\frac{N}{10}$ sodium hydroxide solution (free from carbonate).—One hundred grms. of pure sodium hydroxide are dissolved in 100 c.c. water in a flask covered with tin-foil, and allowed to stand overnight for the carbonate to settle. The solution is then filtered quickly with the aid of the pump through a hardened filter. Ten c.c. are diluted to about $\frac{N}{5}$ strength with distilled water free from carbon dioxide, standardised to phenolphthalein, and diluted to $\frac{N}{10}$ strength. This solution is stored in a bottle coated with paraffin wax and connected by a glass tube with a burette. The bottle and the burette have side-tubes joined to soda-lime tubes to prevent the entrance of carbon dioxide.

$\frac{N}{10}$ Hydrochloric Acid.—The ordinary laboratory solution may be used.

The above solutions, with the exception of the $\frac{N}{10}$ sodium hydroxide, are kept in well-stoppered resistant glass reagent bottles. The only other apparatus required consists of burettes, graduated pipettes, suitable dropping bottles for the indicators, and racks for the test-tubes.

Indicator Solutions.—The following table shows a complete series of indicators which may be used for solutions from $P_H=1$ to $P_H=11$. These indicators are now readily obtainable on the market.

	Strength of Solution.	Range of P_H
	per cent.	
Thymol Blue	0.04 in water	1.2 to 2.8 (pink to yellow)
Brom phenol blue	0.04 " "	5.0 to 9.6 (yellow to blue)
Methyl red	0.02 in 50 percent alcohol	2.8 to 4.66
Brom-cresol purple	0.04 in water	4.4 to 6.0
Brom-thymol blue	0.04 " "	5.2 to 6.8
Phenol red	0.02 " "	6.0 to 7.6
Thymolphthalein	0.04 in alcohol	6.8 to 8.4
		10.0 to 11.0

NOTE.—From Thymol Blue to the last, 1 ml. indicator for definite test of true neutralization, mine waters, &c.).

METHOD OF DETERMINATION

1. *For clear or turbid liquids free from colour.*—The solution to be tested is tried with various indicators until one is found which gives a tint lying between the extremes of colour. Ten c.c. of the solution are then run into a clean test-tube, washed with neutral distilled water, and five or more drops of the indicator solution are added. With a little practice it is easy to judge from the shade of colour roughly what the P_H value is. If the P_H is guessed at 4.0, a mixture of $P_H=5$ is prepared by running in the required quantity of two phosphate solutions from burettes or graduated pipettes. Five drops of the indicator are added, and the colours compared. If the shades of colour do not match, another tube of a different P_H value is prepared until an exact match is obtained.

2. *For Coloured Liquids.*—For this purpose the piece of apparatus known as a comparator is used. It consists of a cubical block of

wood 3½ in. side, with four holes bored vertically to hold four test-tubes. Two holes are also bored horizontally completely through the block, so that it is possible to look through two pairs of test-tubes simultaneously. In hole No. 1 is placed the tube containing 10 c.c. of the solution to be tested, and five drops of indicator. Hole No. 2, behind this, holds a tube containing 10 c.c. of distilled water. In No. 3 we have the tube containing 10 c.c. of the standard solution with five drops of indicator, and behind this, in No. 4, is a tube containing 10 c.c. of the coloured solution. In this way the colour is compensated and we can compare the shades of colour without interference from the colour of the solution. If the colour of the solution is very dark, it may not be possible to distinguish the colour of the indicator, and recourse must be had to the electrometric method. Where a large number of determinations has to be made it is convenient to have racks holding

test-tubes containing a series of standard solutions with the indicator, so that the tubes can be easily picked out for comparison and replaced. In this way a large number of solutions can be dealt with in a very short time. *With practice it is quite easy to get a sufficiently exact idea of the P_H value of a solution by merely adding the indicator without the use of standard solutions, and in many cases this may be all that is required.*

THE DETERMINATION OF ACIDITY OR ALKALINITY OF COMMERCIAL ARTICLES.—The method is very useful where a large number of samples have to be compared for acidity, such as gelatin, flour, starches, milk, sulphur, and many others. For merely comparative purposes all

that may be necessary is to add the indicator to a suspension or solution of known strength and compare the colours without determining the actual P_H value.

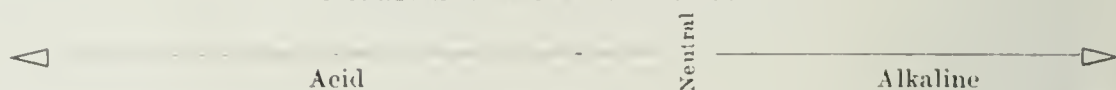
Fine Chemicals.—Every pure salt when in a solution of definite concentration should give a solution of definite P_H value. The method may therefore be used as an indication of the purity of salts and of the presence of an excess of the free acid or base. Where a strong acid is combined with a strong base the P_H of the solution should be about 7. If the base is stronger than the acid the P_H of the solution will be greater than 7, and if vice versa, the P_H will be less than 7.—NORMAN EVERS, *The Analyst*, page 393, October, 1921. (J.M.)

INDICATORS.

P_H VALUES.

	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0
Thymol blue ...	Pink	Orange	Yellow	—	—	—	—	Yellow	Greenish-Blue	—	—
Brom-phenol blue	—	—	Yel- low	Green- ish	Blue- Violet	—	—	—	—	—	—
Methyl red ...	—	—	—	Pink	Orange	Yellow	—	—	—	—	—
Brom-cresol purple	—	—	—	—	Yellow	Green- ish	Purple	—	—	—	—
Brom-thymol blue	—	—	—	—	—	Yellow	Green	Blue	—	—	—
Phenol red...	—	—	—	—	—	—	Yellow	Orange	Red	—	—
Phenolphthalein ...	—	—	—	—	—	—	—	Colour- less	—	Pink	—
Thymolphthalein ...	—	—	—	—	—	—	—	—	—	Colour- less	Blue
	N	N	N	N	N	N	N	N	N	N	N
	10	10 ²	10 ³	10 ⁴	10 ⁵	10 ⁶	10 ⁷	10 ⁸	10 ⁹	10 ¹⁰	10 ¹¹

HYDROGEN ION CONCENTRATION.



STAINLESS STEEL.—In stainless steel has been found a variety which ordinarily will not rust, but there are qualities in it which have so far prevented its use for general purposes, and even in the special uses to which it is put the element of cost is extremely high compared with that of even the most expensive engineering steels. Its discovery was in fact due to experiments for a military purpose, viz., to find a substance resistant to the erosive action of gases in a gun tube. The experiments were conducted only two or three years before the war at the works of Thomas Firth and Sons, Ltd., of Sheffield, and, like a few other important experiments, led to the discovery of something other than had been sought. Of the various alloys tried by the firm one was found to offer a marked resistance to rusting and staining of any kind, and it is this alloy to which is now given the name of stainless steel, its composition being 0.25% to 0.35% carbon, 0.10 to 0.50 silicon, 0.20 to 0.40 manganese, and 12 to 14 chromium. *The Engineer*, in order to collate information regarding the alloy, addressed a number of firms interested, or likely

to be interested in it, and tabulates the replies received under the heads of (a) objections expressed to stainless steel, and (b) some uses of stainless steel. Under the head of objections we have the following: (1) In the manufacture of pipes and tubes the difficulty was found to lie in its welding. The reporting firm stated that towards the end of the war it had two samples of tube rolled from stainless steel, but could do very little with them. (2) Next we have a report on springs made of stainless steel. It is to the effect that with small springs to work in temperatures up to 1,000° F., if the springs are very carefully made and heat-treated they act much better than carbon or other alloy steel. There is, however, a difficulty in reducing the wires to a fine size, when required, such as 1-16th or 1-32nd of an inch in diameter. Further, the heat treatment is liable to spoil the properties of the steel, and it is difficult to re-polish small springs which is a necessary operation in preserving the property of stainlessness. (3) A firm manufacturing centrifugal pumps has found that there is a liability for high speed shafts to seize in the

bearings; its surface is somewhat crystalline and the metal cannot be ground to the same smoothness as ordinary steels. (4) It is reported again that the metal is too hard for such purposes, as pistons and piston rings. The alloy has been tried in other directions but given up, sometimes for its high cost, sometimes because other alloys have proved practically of equal value.

Turning next to opinions in favour of stainless steel, we find that: (1) It is valuable when used in inlet valves of aero engines, mainly because of its high chromium content. (2) Its stainless property has been found valuable in the manufacture of surgical instruments. (3) In the blades of turbines it has been found useful for a few reasons. In one case sample blades to be sent abroad are made of this material because they can be trusted to remain stainless. Then, one firm reports that it has found blades of this material satisfactory with steam at 350lbs. pressure and a temperature of 700° to 750° F. In the matter of drawing instruments, one firm states that it is employing stainless steel for pen points and for the springs of centre screw spring bowls; and another firm that it uses it for the scales of small vernier callipers and are about to make the ordinary type of spring calliper entirely in stainless steel; also that it is contemplating its employment in a few other directions. In connection with pumping machinery, it is reported that the alloy is satisfactory as shafts of plungers, and that notwithstanding its high price it is the cheapest in the long run; its resistance to corrosion is at least as good as that of bronze, it is stronger, and by virtue of its greater hardness, it wears better. A somewhat remarkable direction in which it is largely utilized, though apparently against its natural properties, is in the manufacture of wire and wire ropes. It is said that at least three makers have succeeded in drawing fine wire in one case as fine as gauge No. 28. The firm of Brunton, Musselburgh, says it has in hand orders to a considerable extent for wire ropes in all sizes and types, and with strengths ranging from 80lbs. to 120lbs. per square inch. Tests were made by this firm by immersing a stainless steel wire rope in salt water for a number of hours over a succession of days, allowing it to dry between each immersion, the result being that no pitting whatever took place. As a test against ordinary steel wire rope, a sample of each was exposed to the atmosphere for fourteen days, at the end of which time it was found that though the ordinary rope became badly rusted, the one of stainless steel remained without a speck. For optical work, again, most encouraging reports have been received. One firm is using it to replace prism and silvered mirrors, as it is found to eliminate the errors of parallelism and the non-homogeneity associated with glass, besides securing increased strength and the absence of "silvering" and the troubles arising from its deterioration.—*Ind. Engineering*, page 137, September 17, 1921. (J.A.W.)

QUICK ESTIMATION OF SULPHUR IN COAL.—Total sulphur in coal may be readily determined in the following manner. One gramme of the substance is intimately mixed in a porcelain crucible with two grammes copper

oxide and one gramme anhydrous sodium carbonate. The crucible is placed in a hole in an asbestos pad and heated with a bunsen burner; if stirred occasionally, the action is complete in about two hours. When cool the crucible is transferred to a large beaker and moistened with bromine water to oxidise any sulphites to sulphates; the residue is then treated with hydrochloric acid and bromine water, heated to effect solution, and finally to expel bromine, filtered, and the sulphur estimated in the filtrate in the usual way.—*Ind. Aus. and Min. Stand.*, September 8, 1921, page 455. (C.J.G.)

THE LIME REQUIREMENTS OF SOME SOUTH AFRICAN SOILS.—The term "soil acidity" and "lime requirement" are seldom interchangeable, for the "lime requirement" is affected by the physical condition of the soil and the absence of bases as well as by free acids, whereas "soil acidity," more strictly speaking, should be measured only by the hydrogen-ion concentration.

The term "lime requirement," when applied to soils, is usually expressed in pounds of carbonate of lime per acre of soil nine inches deep, calculated on the basis of 2,500,000lbs.

Summary of Lime Requirements of 127 South African Soils.

	Total soils.
Alkaline	62
Less than 1,000lbs. CaCO ₃ required per acre	21
1,001lbs. to 2,000lbs. CaCO ₃ required per acre	13
2,001lbs. to 3,000lbs. CaCO ₃ required per acre	15
3,001lbs. to 4,000lbs. CaCO ₃ required per acre	4
4,001lbs. to 5,000lbs. CaCO ₃ required per acre	3
5,001lbs. to 6,000lbs. CaCO ₃ required per acre	3
6,001lbs. to 7,000lbs. CaCO ₃ required per acre	2
Above 8,000 CaCO ₃ required per acre	4
Total	127

The Veitch Lime Requirement Test consists of taking several 12-grms. portions of the soil and digesting with varying known volumes of lime water diluted with distilled water, till there is obtained a test which finally indicates alkaline to phenol-phthalein.

The total lime contained in the soil as found by hydrochloric acid extraction has no bearing on the "lime requirement" of the soil.

A number of crops can be more successfully grown on soils of high "lime requirement" than on soils which have received the required lime. These are: maize, rye, oats, Irish potatoes, sweet potatoes, cow peas, velvet beans, carrots, flax and all berries.

About 93% of our soils are deficient in phosphorus, and until this deficiency is remedied farming will not pay. THOMAS D. HALL, B.A., M.Sc. *Journal of South African Association of Analytical Chemists*, July, 1921, page 3. (H.D.B.)

THE CORROSION OF IRON AND STEEL.—A valuable paper on the above, with special reference to reinforced concrete, is published in Volume

IX. of the Concrete Institute, the author being J. N. FRIEND.

Corrosion was known nearly 2,000 years ago to Pliny, who waxes eloquent on the subject of rust. At the present day the subject demands thorough scientific study.

The conditions essential to corrosion are now fairly well known. Air-free water alone is without appreciable action upon iron at ordinary temperatures. Water vapour the same. Dry air or dry oxygen the same; but when the temperature is raised to 220° C. iron acquires in this contact a pale-yellow tint, and at higher temperatures passes through the range of tempering colours, caused by this superficial layers of oxide. This oxide is not produced by similar heating *in vacuo*, but occurs in contact only, even if the air is perfectly dry. These layers of oxide differ materially from rust, and tend to protect the metal below.

A mixture of water vapour and air is without action on iron at ordinary temperature provided no liquid water is allowed to condense on the metallic surface. If condensation occurs through fluctuations of temperature, corrosion readily occurs. This disposes of the possibility that rusting is a simple case of direct oxidation such as occurs when the metal is heated in air.

It is clear that oxygen and liquid water are essential to corrosion. The paper proceeds to deal with the chemical nature of rust, and states it to be essentially hydrated ferric oxide, aggravated by impurities contained in the air. The great danger in reinforced concrete is the expansion of iron in rusting. Cracks in the protective covering are inevitable, admitting more and more air and water to add to corrosion.

Sea-water at ordinary temperatures is considerably more corrosive than fresh water at temperatures below 58.4° F., but less corrosive above this temperature. The practical importance of this is, that in warm seas, the salt water is less destructive than fresh; while in cold seas, the contrary is the case.

The effect of alkalies upon corrosion is then discussed, and the practical results on boilers of weak alkaline feed-water as likely to produce serious trouble insisted upon.—J. N. FRIEND, *Ind. Engineering*, page 36. September 3, 1921. (J.A.W.)

THE HANDLING OF FUSIONS IN PLATINUM CRUCIBLES.—When fusions are performed in large dishes no particular trouble is experienced in dissolving the fused mass, but if done in deep crucibles it is better to first empty them. Many devices have been proposed, but they generally only succeed with new crucibles, and are apt to spoil them in the long run. The author now operates as follows: As soon as the fusion is completed the coiled end of a platinum wire is put into the mass, which is then allowed to cool. The platinum wire is about 10 c.m. long, and ends in a loop, so that it may be suspended from a hook. When suspended, the crucible is brought at about half an inch distance from a pipe clay triangle, and then suddenly heated. In a few seconds the crucible will detach itself and drop into the triangle, whilst its contents stick to the wire. The small quantity of salts still adhering to the crucible may, of course, be removed by

suitable means. The wire is now hung into a beaker filled with water or acid, when owing to the salts being on the top of the liquid, solution takes place with great rapidity.—L. L. DE KONINCK, *Zeitsch. f. anorg. Chem.*, 20, 6th October, 1921, page 639. (C.J.G.)

THE ART OF LIME BURNING.—Each individual limestone requires its own peculiar heat treatment to produce a lime of desired quality. A certain limestone, for example, may best be hard-burned slowly at low temperature for furnishing lime to a causticizing plant. It may be light-burned at low temperature for building lime, and it may best be light-burned quickly at high temperature for lime to go to the hydrating plant.

Lime burning should be conducted under stabilised conditions of physical and chemical control. The demands on a modern lime kiln are as follows:—

(1) Continuous mechanical feed of rock and continuous mechanical discharge of lime. When lime is properly burnt it should be immediately taken away, not left to soak in the heat and gases for four to six hours.

(2) Positive control of temperature.

(3) Positive control of draft.

(4) Control of burning period and lime discharge.

(5) Control of combustion.

(6) Minimum temperature of flue gases and

cool lime for immediate handling and shipment as it leaves the kiln.

New kilns are now being built to meet all these control conditions. The limestone is properly crushed and fed to the kiln by special loading mechanism. The kiln is fired with producer gas, temperatures and draft being automatically recorded by instruments and subject to close adjustment. The lime discharges continuously through an annular opening at the bottom and is transported by conveyors to steel bins which again have mechanical means for discharging into containers.—G. B. WOOD, *Chem. and Met. Engineering*; Paper presented at Meeting of Lime Association, New York, by G. B. WOOD, October 12, 1921. (F.W.)

ESTIMATION OF SMALL AMOUNTS OF IRON AS THIOCYANATE.—The colorimetric method of estimating small amounts of Fe as thiocyanate has been developed by R. Wilstatter, as recorded in the *American Journal of Science*. From 1 to 2 c.c. of concentrated HCl is added for each c.c. of solution holding the iron, followed by sufficient 40 per cent. ammonium thiocyanate solution to bring the bulk up to 50 c.c. In this way an intense coloration is obtained from small amounts (0.1-0.02 mg.) of iron. The colour comparisons must be made promptly, because the red gradually fades. If iron present in the ammonium thiocyanate gives the 40% solution a red colour, this may be removed by boiling till the red colour disappears, after which it does not return upon cooling.—R. WILSTATTER, *American Journal of Science*, through *Chemical Engineering and Mining Review*, September 5, 1921. (H.R.A.)

METALLURGY.

THE SEPARATION OF SPHALERITE, SILICA AND CALCITE FROM FLUORSPAR.—A comparison between electrostatic separation and flotation results leads to the conclusion that flotation will yield a slightly higher-grade zinc concentrate with a much higher recovery, but that a marketable spar can be obtained by flotation only by sacrificing a large amount with the silica and the calcite discarded on the tables, while practically any grade of spar can be obtained electrostatically.

The crushing of the ore to 10-mesh for electrostatic separation instead of to 65-mesh for flotation is greatly in favour of the former.

While flotation will give a slightly higher grade zinc concentrate and a greater recovery, this is partly overcome by a better market price for the electrostatic concentrate owing to its coarser condition.

The drying of the ore before electrostatic treatment is not so difficult or expensive an undertaking as the drying of both the flotation concentrate and the tailing (spar).

As there seems to be considerable doubt among mining men as to the reliability of operating electrostatically in wet weather, it is suggested that before an electrostatic installation is decided upon, a machine be tried on a working scale under all possible conditions.

Details of the methods employed in actual tests, and of the results obtained, are given in the original paper.—J. Gross, *The Chemical Age*, page 518, October 29, 1921. (R.A.C.)

ZIRCONIUM—“THE MYSTERY METAL.”—On account of various mysterious properties and uses that have been attributed in the popular mind to zirconium, an investigation regarding the preparation and uses of metallic zirconium and its salts has been conducted by the U.S.A. Bureau of Mines, and the results have just been made public.

Sintered or coherent zirconium metal is very resistant to acids, and can be used for electrodes, steel containing zirconium has been proposed for use in armour-plate and automobile parts, and nickel-zirconium alloys have been suggested for high-speed cutting tools and for cutlery.

Coherent white zirconium metal may serve as a substitute for platinum in certain cases.

Zirconium oxide is a valuable refractory, having a low coefficient of expansion, high melting point and great resistance to slag corrosion. It is recommended as an abrasive, a pigment in paints and an opaquing agent in enamels. Being absolutely non-poisonous, the oxide is used in place of barium compounds in Röntgen therapy, and it is also said to have some medicinal value.

Zirconium oxide and nitrate have been suggested for use in the extraction of oxygen and nitrogen from the air. Zircon is found in considerable amounts in many places in deposits derived from disintegration of granitic and pegmatic rocks, and it also found most abundantly in certain varieties of Norway, and occurs in crystalline limestone at Grenville and elsewhere in Canada. In Brazil the ore is mined in large amounts by primitive methods.

The results of the investigations of the Bureau of Mines are available in Bulletin 126—“Investigations of Zirconium. With Especial Reference to the Metal and Oxide,” by J. W.

Marden and M. N. Rich, which is distributed by the Superintendent of Documents, Washington, D.C., 25 cents.—U.S.A. BUREAU OF MINES, *The Chemical Age*, page 561, November 5, 1921. (R.A.C.)

LEACHING IRON ORES FOR PHOSPHORUS.—The phosphorus content of an iron ore is a determining factor as regards the value of the ore and also its metallurgical treatment. If some method of treatment such as concentration, leaching, etc., could be used, and the phosphorus content of the ore reduced, it would be an important advancement in the iron mining industry towards the utilisation of high phosphorus ores.

The statement has been made that iron ore piles on long exposure to the atmosphere often decrease their phosphorus content.

The author describes a series of experiments on the leaching of iron ores to determine the economic possibility of reducing the phosphorus percentage. High phosphorus ores containing 0.2–0.12 per cent. P were agitated from two to ten hours with various solvents. The solvents included hydrochloric, nitric and sulphuric acids of from 0.1 to 2.5 per cent., sodium hydroxide from 0.2 to 0.8 per cent., and 2 per cent. citric acid and ammonium citrate.

Two sizes of ore were tried, 100 and 300 mesh, but since anything below 100 mesh is too fine for practical purposes, results from the finer product were of only comparative value. Sulphuric acid proved to be the best solvent, and hydrochloric acid the poorest, and in all cases the amount of phosphorus dissolved was greater with the higher concentrations of the solvents, showing that equilibrium was not reached.

Under identical conditions the phosphorus extracted from a brown ore was nearly twice the amount extracted from Guyana ore.

The maximum extraction of phosphorus by leaching was negligible from a commercial viewpoint, and the conclusions to be drawn are, that while the leaching of phosphorus from iron ores of the types experimented with presents many points of scientific interest, the method is not commercially feasible.—R. M. Winstow (U.S. Bureau of Mines: Reports of Investigations), *The Chemical Age*, page 519, October 29, 1921. (R.A.C.)

MODERN DEVELOPMENTS IN NON-FERROUS METALLURGY.—The apprehension of the essential nature of metallic mixtures as coming within the bounds of physico-chemical laws governing solutions with its necessary concomitants—heating and cooling curves and equilibrium diagrams—has opened up a vast area of possibilities of new knowledge. Such new knowledge is now sought not only in university and in other research laboratories of similar standing, but in industrial and works laboratories in close co-operation with works practice.

Birmingham has led the way in a most interesting development of the application of science to industry in the establishment of a co-operative laboratory. Ten non-ferrous works combined with the object of equipping and staffing such a laboratory as would be entirely adequate for their needs, and very greatly superior to that financially possible to a single firm. This laboratory does not confine itself

to the purely metallurgical side of works practice, but concerns itself in the qualities of all the materials used—*e.g.*, oil, fuel, refractories, and general materials; as also efficiency of furnaces, etc.

In no section of non-ferrous metallurgy has more intensive scientific and industrial research work been done than in aluminium and aluminium rich alloys. The introduction of "Duralumin," which contains copper, magnesium and silicon in addition to aluminium probably marks the earliest stirrings of general industrial interest in the light alloys.

A number of other alloys are now being made as a result of modern researches carried out in the National Physical Laboratory and elsewhere.

Several of these at least deserve brief mention even in a cursory review of the subject, particularly the N.P.L. high tensile alloy, which consists of:—

Copper	2.5 per cent.
Zinc	20 per cent.
Manganese ...	0.5 per cent.
Magnesium ...	0.5 per cent.
Aluminium ...	76.5 per cent.

After heat treatment the wrought alloy gives a maximum stress value of nearly 40 tons per square inch.

Another closely similar alloy is that known as the 3/20 alloy, containing copper 3 per cent., zinc 20.0 per cent., aluminium 77 per cent. This material is not so strong as the N.P.L. alloy, but does not require heat treatment.

A third alloy has the approximate composition of copper 4 per cent., nickel 2 per cent., magnesium 1.5 per cent., aluminium 92.5 per cent. This alloy promises well as offering a high resistance to corrosion: it is generally known as the "Y" alloy.

The foregoing alloys are all used as wrought alloys. The manufacture of nickel and nickel alloys has also made considerable advances recently.

The copper rich nickel alloys, notably the 85/15, 80/20 and 75/25 alloys, all possess appreciable tensile strength and exceptional ductility, being very suitable for deep stampings, etc., and being reasonably hard, very tough, and resistant to corrosion are suited to a variety of industrial uses. Nickel rich alloys are even more valuable, being superior to the whole range of copper alloys in such properties as tensile strength, toughness and resistance to corrosion.

Alloys containing more than 50 per cent. nickel show only negligible loss after immersion in boiling 20 per cent. sulphuric or hydrochloric acid for several hours.

"Monel" metal has been shown to be distinctly superior to any known copper alloy at present on the market for use under stress at temperatures of the order of 300° or 400°C. In the nickel binary alloy class, nickel-manganese containing about 10 per cent. manganese has been found valuable for such work as sparking-plugs, valves, etc.

In the German or nickel-silver class alloys have been developed suitable for "hot-working" in drop stampings and forgings.

Nickel chromium alloys have most valuable acid and heat-resisting properties, in addition to being important electric-resistance materials.

Alloys of nickel and chromium containing little more than 2 or 3 per cent. of iron possess appreciable tensile strength at temperatures approximating 1,000° C., and do not scale. In the copper and brass sections, the last decade has marked a distinct advance in standards of quality, although no outstandingly new alloys have been introduced. In spite of the excellent qualities of aluminium bronzes they have suffered from the competition of the high tensile brasses, which are distinctly cheaper and easier to manufacture. These high tensile brasses, based on 60 per cent. copper and 40 per cent. of zinc, to which are added such metals as iron, nickel, manganese, tin and aluminium, are of great value.

Suitable alloys for die casting are being developed; up to the present zinc rich alloys have mainly occupied this field, but attempts are now being made to develop alloys of greater tensile strength.

In the production of non-ferrous metals no revolutionary development can be recorded; the older coke-fired pit type of crucible furnace, with certain modifications, still holds its own. Oil-fired annealing furnaces are proving to have distinct advantages.

Much earnest attention is being given to the subject of industrial scientific research, in which connection it is hoped that the British Non-ferrous Research Association will prove of great value.

It is clear that the future success of British industries depends almost entirely on the human element, *i.e.*, on hard work combined with high ideals of quality of production, intelligent organisation and bold exploration of new fields.—W. R. BARCLAY, *The Chemical Age*, page 514, October 29, 1921. (R.A.C.)

MINING.

SPONTANEOUS COMBUSTION OF COAL IN MINES.
—(The Final Report and Recommendations).
—Nine years ago there was appointed in England a Departmental Committee to report on Spontaneous Combustion of Coal in Mines. It consisted of Mr. (later Sir) R. A. S. Redmayne, H.M. Chief Inspector of Mines; Sir Arthur B. Markham (subsequently succeeded by Mr. J. H. W. Laverick); and Messrs. C. E. Rhodes, F. Digby and H. Smith. They were to enquire into the circumstances in which spontaneous combustion of coal occurs in mines, its causes, and the means of preventing it or dealing with it when it has arisen. An interim report was issued in December, 1913, on that part of the enquiry relative to the danger to persons employed in a mine during the occurrence of an underground fire occasioned by the spontaneous combustion of coal or other carbonaceous material.

The final report of the committee was published in London on August, 1921, as a Blue Book of 114 foolscap pages. It gave a historical review of the subject, an account of scientific views as to the initiation of spontaneous combustion, a review of the practical aspect of the subject as applied to coal mines, dealt with hydraulic stowage, and wound up with various conclusions, recommendations and appendices.

The main conclusions arrived at, after weighing all the evidence as to the scientific explana-

ation of the self-heating of coal, are as follows:

(1) That the self-heating of coal is not in any way due to the presence of bacteria, and that bacterial action, even if it occurs in coal, does not account for even the initial stages of self-heating.

(2) That some small amount of heat may be developed by the oxidation of pyrites in coal when it occurs as an amorphous form of marcasite; but that, as pyrites is present in coal in such small proportion as compared with the coal substance proper—which is a bad conductor of heat—the effect of this heat is negligible. The chief part played by pyrites when present in an unstable form is that of a disintegrator of the coal, so rendering the latter more permeable by air and exposing a greater area of coal substance to oxidation.

(3) That the presence of moisture in coal has an accelerating effect on its oxidation, and consequently that coals high in hygroscopic moisture absorb oxygen more readily than those of low moisture content.

(4) That the self-heating of coal is mainly due to the absorption of oxygen by the coal resulting in the generation of heat.

(5) Though coal absorbs both oxygen and nitrogen in a physical sense as well as in a chemical sense, the absorption in so far as heating effects are concerned is a chemical and not a physical process; that the chemical process is mainly one of attachment of oxygen to molecules of high carbon content, but that subsidiary to this, and playing an important part in determining the actual spontaneous ignition of coal, is a chemical interaction between the oxygen thus loosely held by the carbon-like molecules and other atoms in these molecules or other portions of the coal conglomerate.

(6) That, from the chemical standpoint alone, the higher the percentage of oxygen contained in a coal the greater it would seem, the liability to spontaneous combustion.

(7) That the texture of the coal is a matter of great importance, seeing that the more permeable is a coal, other things being equal, the greater are the effects of oxidation, inasmuch as a greater surface is exposed to the action of the air as compared with a coal of closer texture.

(8) That as the temperature rises the rate of absorption of oxygen increases.

The main conclusions reached by the commission regarding the practical aspect of the subject, also after careful consideration of the evidence, are briefly summarized below:—

(1) *Liability of Coal to Spontaneous Combustion.*—Probably all bituminous coal is liable to spontaneous combustion to some degree, but the fact that there is greater liability to self-heating of the coal in the seams of some coal fields of the United Kingdom than in others, is due to several causes other than the chemical composition of the coal itself, viz. Thickness of Seams. Speaking generally, the thicker the seam the greater the liability to spontaneous combustion. With rare exceptions the heating process, in natural coal less than four feet in

thickness, is not carried to such an extent as to induce combustion. (b) *Crushing of Pillars.*

Coal which has become crushed in the mine by reason of superincumbent weight is more likely to induce self-heating than coal in a solid compact state. For this reason it is in the highest degree desirable that (in seams liable to spontaneous combustion) pillars should be adequately designed to resist all pressures, and that during the process of their removal (which should not be long delayed) work should be as consistent and rapid as possible. For the same reason inferior coal normally left, e.g., in the vicinity of faults, should be extracted and sent out of the pit.

(2) *Faults.*—Faults indirectly contribute to the self-heating of seams of coal, which without these extraneous agencies might not take fire. This is due not only to the presence of inferior and soft coal adjacent to the faults, but also to the interference of the latter with the regularity of the line of face, and to their constituting lines of weakness contributing to falls of roof and admission of air.

(3) *Condition of Roof.*—The character of the roof of a coal seam plays an important part in the liability of the coal to spontaneous combustion. A broken or unstable roof permits the percolation of air, and the leaving of top coal for its maintenance introduces a factor conducive to fire in the goaf when such coal breaks down too far back for complete recovery.

(4) *Other Conditions.*—The following conditions are also conducive to spontaneous combustion:—

(a) *The Evacuation and Incomplete Settlement of the Goaf, Gob or Waste.*—Where this occurs the goaf has large spaces to which sufficient air may have access to promote the oxidation of any carbonaceous material present, but in which there is no constant through current to provide a counteracting cooling effect.

(b) *The Leaving of Timber in the Goaf.*—Timber left standing in the waste workings of a mine is not a primary cause of spontaneous combustion. It is so indirectly, inasmuch as it hinders the even settlement of the roof, and allows of the formation of cavities or air-spaces. It may be, also, that in the presence of timber, which is more easily ignited than coal, fire breaks out at an earlier stage of heating than it otherwise would. In mines liable to spontaneous combustion, therefore, the extraction of timber should be carried out as far as is compatible with safety.

(c) *The Presence of Coal and Timber in the Pucks.*—We are aware that there are cases where coal has been largely used in the construction of pucks without the liability to spontaneous combustion being incurred therein, but this has been because of the peculiar character of the coal so employed. In fact witnesses almost unanimously condemned the practice and undoubtedly, it has in the past been a frequent cause of fire. No timber should be either built in or used as a roof support in the construction of pucks, except in the case of cuts or chocks placed on the road-side of pucks when these cannot be dispensed with, e.g., in highly inclined roadways.

(5) *Systems of Working.*—With regard to this aspect of the case, it is impossible to lay down any hard and fast rule for universal application, and the method adopted must be conditional on the circumstances. Broadly speaking, we are satisfied that the methods of working in operation in the several districts with which we have dealt, are those which are the most practical, and which, in the circumstances, are best calculated to get the coal with the least risk of danger from fire, affording at the same time the greatest facilities for dealing with outbreaks. In some cases, however, the manner in which these systems are carried out in detail is not, in our opinion, as perfect as it might be, and we have pointed out some of the deficiencies in the body of this report.

In all mines liable to spontaneous combustion the following precautions in respect of methods of working are desirable:—

(a) *Longwall Method.*—Wherever the natural conditions (*e.g.*, thickness and inclination of the seam, and character of the roof) allow of its application, the longwall system of working should be practised. The face should be kept as straight as possible, and advanced consistently and rapidly.

(b) *Retreating Method of Longwall.*—In those seams which give off fire-damp freely, and which by reason of their thickness are suitable for its application, the retreating method of longwall should be adopted.

(c) *Packs.*—Packs should be made as wide as practicable in relation to the distance between "gates." The thicker the seam the wider should be the packs, which should be solidly built and well-faced.

(d) *Gate Roads.*—The distance between the gates should be such as, whilst permitting of the quick, regular, and complete settlement of the goaf, to reduce the number of gate roads to the minimum, so decreasing the possibility of leakage of air. Where practicable the packs should be buried as soon as possible.

(e) *Panel Systems.*—Where experience has shown that the system of working—whether modified longwall or pillar and stall—should be by panels, the immediate entrance to each panel should be limited to two roads provided with arrangements for rapid and effective sealing-off in case of an outbreak of fire.

(f) *General Precautions.*—All roads no longer required for haulage, travelling, or ventilation should be closed with good air-tight packs, so that there will be less liability of spontaneous combustion taking place therein. Such roads as may be required to be kept open should be travelled and examined daily.

As a high pressure of ventilating current conduces to leakage, it should not exceed what is necessary to ventilate the mine properly, and the space between the face and the gob should be sufficiently large to prevent the forcing of air through pack walls. Generally, the airways should be of large area, and there should be a large number of splits. The ideal in ventilation is a large quantity of air at a low water gauge; leakage of air into undesirable places will thus be reduced to a minimum.

No coal posts or pillars should be left, if possible. No slack or coal should be left in the goaf.

Where heatings or fires are of frequent occurrence, an adequate supply of water (under pressure) should be provided for immediate use where advisable.

(6) *Organisation.*—At large collieries liable to spontaneous combustion there should be provided a specially trained official or officials, whose duty it should be to investigate any occurrence of gob-stink or other indication of self-heating, and to deal with any outbreak of fire. These officials should be under the direct control of the certificated manager of the colliery and report to him daily.

We recommend to the serious consideration of colliery owners and managers the organisation set up by Mr. J. T. Greensmith, at Brodsworth Main Colliery. Perhaps more is to be hoped for from organisation such as this and from precautions adopted as the result of practical experience than from any other source. It is a fact that since the commencement of our enquiry in 1912, when considerable apprehension existed in the minds of many as to the future of the South Yorkshire coalfield owing to the prevalence of gob fires, a very marked improvement has taken place, and fires are now, comparatively speaking, of rare occurrence.

(7) *Hydraulic Stowage.*—We commend to the careful consideration of mining engineers the report by Mr. Seidl on Hydraulic Stowage, and the evidence of other witnesses, especially that of Mr. R. Kirkby. There is no doubt that the application of the process would result in a diminution—probably in the complete prevention—of gob-fires, but the application of the process necessitates ample quantities of easily accessible and suitable stowage material. The process has been successfully applied in the Fifeshire coalfield.

(8) *Cementation.*—We recommend that mining engineers should consider the application of the cementation process of combating fires that have occurred in main roads, ribs, and pillars.

The committee does not recommend the establishment of regulations additional to those brought into force in July last, which were based upon the interim report, and which are regarded as sufficient under present circumstances. *Industrial Australian and Mining Standard*, October 6, 1921, pages 612, 613. (C.J.G.)

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AT

Ordinary General Meeting, 18th February, 1922.

The Ordinary General Meeting of the Society was held in the Assembly Hall, Scientific and Technical Club, 100, Fox Street, Johannesburg, on Saturday, the 18th February, 1922, at 8 p.m., Mr. F. Wartenweiler (President) in the chair. There were also present:—

17 Members: H. R. Adam, C. J. Gray, J. Hayward Johnson, Dr. A. J. Orenstein, J. R. Thurlow, Prof. G. A. Watermeyer, John Watson, A. Whitby, H. A. White, Prof. J. A. Wilkinson (Members of Council), R. A. C. Cooper, H. L. V. Durell, Jas Gray, W. C. Lindemann, T. Graham Martyn, W. E. Thorpe, and H. R. S. Wilke.

4 Associates: W. Anderson, J. A. Boyd, C. E. Deakin, and O. A. Gerber.

1 Visitor and H. A. G. Jeffreys (Secretary).

MINUTES

The Minutes of the Ordinary General Meetings, held on the 15th October and 19th November, 1921, as reported in the October and November Journals, were confirmed.

NEW MEMBERS

A ballot was taken for the election of new members, and the following were declared unanimously elected:—

Garnsworthy, R. L., 25a, Chudleigh's Buildings, Johannesburg, Doctor of Medicine.
Trenby, W. E., Robinson Deep, Ltd., P.O. Box 1392, Johannesburg, Mining Engineer.

The Secretary announced that the following gentlemen had been admitted as Associates:—

Donald J. E., P.O. Box 491, Johannesburg.
Lowry, Win., Scientific and Technical Club, 100, Fox Street, Johannesburg.

CONTRIBUTIONS TOWARDS MAINTENANCE OF THE ASSOCIATED SCIENTIFIC AND TECHNICAL SOCIETIES OF SOUTH AFRICA.

The President said he had to bring before the meeting a rather important matter, namely, confirmation of the action of their Council in regard to the contribution of the Society to the Associated Scientific and Technical Societies of South Africa. He would read them the recommendation:—

"The Controlling Executive of the Associated Scientific and Technical Societies of South Africa, confronted by the necessity of making provision for an annual income of approximately £1,700 to cover interest on mortgages and other expenses incidental to the maintenance of the Associated Societies, has decided to make an assessment on its Constituent Societies.

This assessment has been made in the manner following:—

In respect of members residing in the Witwatersrand area (Springs to Randfontein inclusive) a sum calculated at the rate of £1 1s. per member per annum.

In respect of members residing elsewhere in South Africa (South of the Equator) a sum calculated at the rate of 10s. 6d. per member per annum.

Members of more than one Constituent Society will only be called upon for one contribution, and may choose through which Society they will pay. In the event of such members failing to notify their decision by the 30th June, 1922, the Controlling Executive will determine which Constituent Society shall collect the contribution.

The advantages which the Chemical, Metallurgical and Mining Society of South Africa derives from its connection with the Associated Scientific and Technical Societies of South Africa must be obvious to all members, and it is earnestly hoped that every member will respond to the call so as to

enable the Society to provide its quota to the general contribution.

The Council of the Society has adopted this means of levying on its members in preference to increasing the annual subscription: should, however, the levy fail to produce the requisite amount, the question of an increased subscription will have to be seriously considered."

The President remarked further that this action had been taken by the Society's representatives on the Executive Council of the Associated Societies in conjunction with representatives of all other Constituent Societies. The Council had confirmed this method of levying its quota, and they now asked members to confirm their action.

Mr. Jas. Gray had much pleasure in proposing that the recommendations of the Council in connection with the assessment placed upon the Society by the Controlling Executive of the Associated Scientific and Technical Societies of South Africa be confirmed. In supporting the proposal he did not think there was much further to be said. When the scheme was originally proposed their Society was one of the trinity responsible for the scheme of joint housing which they saw to a certain extent in its fulfilment to-day, and he thought it would not be right for the Society at this very late hour of the day not to confirm the Council's action.

The building required quite a considerable sum for the purpose of maintenance, and the Associated Societies also required a large sum for the carrying on of their necessary activities. Although their activities in the past had not been as great as they would like to have seen, yet he was satisfied that in the future they would be not only to the advantage of the Scientific and Technical Societies and their members, but to South Africa at large. Therefore he felt that the Society must support the scheme which had been placed before it that evening. It was a scheme which had been arrived at after considerable discussion among the representatives of the different societies on the Controlling Executive, and had met with unanimous approval. He did not see how they could expect to carry on unless they got some assessment of that nature. After all, he did not think that the assessment on the Witwatersrand Members was by any means too large, considering the advantages they derived, and he personally would have been only too pleased to see it doubled. He commended

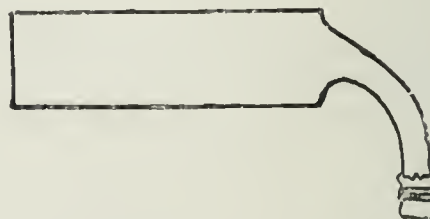
the scheme to their earnest consideration, and was satisfied that members would support it whole-heartedly and that there would be no necessity to adopt any other means for raising the sum required of the Society.

Mr. H. R. S. Wilkes had very great pleasure in seconding the proposition. What Mr. Gray had said had practically covered the whole question, and he (the speaker) could add very little to it. He was glad the decision of the Committee was to make it a levy rather than to increase the subscription. It seemed to him, in the event of the levy not being a successful one, the idea of increasing the subscription would be quite a good thing because, for two guineas, they really were getting a very cheap subscription, and the subscription of most of the other Societies was greater than that. He trusted the proposition would be carried.

Declared carried.

EXHIBITION AND DEMONSTRATION OF DEVICES OF PRACTICAL ADVANTAGE.

Mr. J. Madden: Through the introduction of Mr. H. A. White, I bring before your notice a new design of mercury container for use by amalgamators. It is made from a 6 inch length of $1\frac{1}{2}$ inch pipe. A plate is welded into the bottom and another at the top, and into this a standard $\frac{1}{2}$ inch bend. The usual amalgam cloth is fastened to the outlet of this bend. It is a simple device and an improvement on the ordinary hand mercury bottle. It directs the mercury to the plate or spot where it is wanted, prevents indiscriminate splash, and therefore waste.



Mr. H. A. White thought they ought to offer a special welcome to a device of that nature because some of the members of the Society and others had been taking a very keen interest in the prevention of mercurial poisoning on the Witwatersrand, and any matter which they could bring forward before the members of the Society which would render the use of mercury safer was a thing to which they must undoubtedly give the heartiest welcome and the best possible reception.

It seemed a very simple and ordinary little device, but he had no doubt it required ingenuity to develop it; however, he thought the best way in which they could show their appreciation of it was to adopt the idea and put it into use.

Mr. Madden said he had personally tried the bottle and found it worked very well.

OBITUARIES.

The President regretted to have to announce the death of three of their members since the last meeting, namely, Dr. Alex. Heymann, Major L. A. E. Swinney, and, very recently, Mr. J. Martin, of New Modderfontein. He called upon members present to pass a vote of condolence and to rise from their seats out of respect. (All the members present did so.)

ACTION OF CONTROLLING EXECUTIVE OF A.S. AND T.S.S.A.

The President said he would like to refer to the action taken some time ago by the Society's representatives on the Controlling Executive of the Associated Scientific and Technical Societies of South Africa

in supporting certain resolutions pertaining to the existing industrial crisis. He assumed that they met with the confirmation of members and that they were in full sympathy and agreement therewith.

FERREIRA DEEP DISASTER.

The President announced that this was the first meeting of the Society since the regrettable Ferreira Deep Mine disaster in December. As all members present knew, in fighting the fire five men were entombed by a fall of rock in the shaft. Rescue parties worked ceaselessly for days in an endeavour to save two of the men who were alive, but pinned down. Despite their efforts, and, being in imminent danger from further falls of rock and gasses from the fire, they were unable to bring these men out alive. It was fitting that the Society should place on record its sincere sympathy with those bereaved and its appreciation of the spirit of sacrifice, courage and endurance of the rescue parties. He would ask members present to stand in silence. (All present rose.)

Prof. G. A. Watermeyer then took the chair

FEATURES OF METALLURGY OF A REFRACTORY GOLD ORE.

By F. WARTENWEILER, A.I.M.M.

During 1914 and 1915 the writer had the privilege of a close acquaintance and the responsibility of recovering the precious metal content of a refractory gold ore. It was that mined at Prestea Block A, situated in Gold Coast Colony, Equatorial West Africa. It was refractory in the sense of obstinacy in yielding its treasure to treatment. In a paper*, published by the I. M. & M. London, the sodium sulphide process developed and applied at this mine was described by the writer.

In turning to the metallurgy of this extraordinary ore at this late date I have been influenced by the belief that a record of its salient features will prove of interest. The paper deals with the process as used during the period referred to and with investigations which had as their object the possible application of developments in gold metallurgy elsewhere. Having been out of touch

with the mine during recent years, I am unable to describe current practice with authority.

HISTORY.—Ore treatment at this mine probably traces back centuries, in common with that of Ashanti gold deposits. It is known that in the days of ancient, prosperous and powerful States in North Africa, such as Egypt and Carthage, gold was received from the regions to the south of the Great Desert. To this day the natives of the semi-arid region bordering the Southern Sahara are in a state of comparatively advanced civilization and carry on a trade across the vast expanse of the desert. The Fanti natives of the jungle to the south and then women folk are adorned with gold jewellery of varying degrees of purity, manufactured by native goldsmiths, and gold is finding its way northward via the Hausa trader. When Jason of the Argonauts sought gold which had been recovered by means of fleece, the

* "The Sodium Sulphide Process of Gold Recovery," Trans. of I.M.M., July, 1918.

Gold Coast native was applying crude metallurgy to the deposits in the streams and the jungle enclosed outcrops.

The European of our time, who had ventured to work the Prestea deposit, not being content with such slow methods, which, however, have the merit of conservation, provided stamps and amalgamating plates to deal with the oxidised ore at shallow depths. When the sulphide zone was reached and with it the association of gold with refractory sulphides of arsenic and antimony, it was realised that if the mine were to survive, different methods must be employed. Australian metallurgical methods for the treatment of refractory gold ores were at this time prominently successful and were therefore, and not without good reason, adopted.

DESCRIPTION OF ORE.—Prestea ore is a white quartz, brecciated and seamed with soft carbonaceous schist which also occurs as a selvage between the lode and the wall rock. The auriferous mineralisation is distributed throughout the lode matter and consists of free metallic gold and that associated with iron pyrites and the arsenical and antimonial sulphides, mispickel and stibnite; zinc blende is also present. The mineral sulphides are found throughout the lode matter and not uncommonly in the graphitic schist. The mill pulp derived from this assumes a black colour.

FLOW SHEET.—The outline of treatment is illustrated in the accompanying flow sheet. In studying this it will be noted that contrary to Rand practice, sorting is omitted. Sorting on an ore of this character with the object of eliminating the objectionable graphitic schist would appear to be highly desirable and is so in the abstract until one examines practical considerations. The graphitic schist breaks up easily, in many instances "flows" of this unctious material have been experienced underground. In sorting practice it would, to a great extent, pass through the grizzlies and reach the mill as unsortable fines. Furthermore, the lode matter itself, being brecciated, contains graphite. It was experienced that clean mining was of the greatest assistance to the

metallurgist in his endeavour to obtain a reasonable extraction.

In stamping, a high water/solid ratio ($\frac{9}{1}$) was found necessary to wash the frequently sticky ore through the screens. A Higham automatic sampler, its slot traversing the pulp stream, gave a reasonably close valuation of the mill heads. The first set of spitzkasten did not function for the reason that its dilute overflow served to provide water for a free discharge of pulp from the first stage grinding pans.

The cyanide leaching and sulphide post treatment were consecutive operations, conducted in the same vat. The Reduction Plant being positioned on a rather steep hill-side with the stamp mill on the crest, the flow of pulp depended entirely on gravity. The water only was returned. The tonnage of ore sent to the plant fluctuated; 25,000 tons milled per month may, however, be accepted as meeting its capacity.

METALLURGICAL ANALYSIS.—The distribution of gold recovered and gold discharged, and its incidence in the entire scheme of treatment, is shown in Tables I and II, and is based on typical results.

Amalgamation played a large part, being responsible for 65.64 per cent. of the extraction and accounted for 76.51 per cent. of the total recovery. The cyanide treatment of sand impresses one with its relative unimportance, considered from the point of view of percentage of gold recovered. As the gold extracted by the post treatment with sodium sulphide was originally dissolved by the cyanide solution, the recovery due to the combined treatment should perhaps be bracketed. This would advance the total incidence of extraction by cyaniding to 20.15 per cent. of the original value of the ore and 23.49 per cent. of the total recovery.

Under the heading "Distribution of Discharge" it should be stated that the slime was accumulated for future treatment, should such be commercially justified. It need not therefore be written down as a total loss.

The numerous sources of recovery are an outstanding feature, and reflect the complexity of the metallurgy employed:—

PRESTEA FLOW SHEET.

FLOW

DESCRIPTION

GRADING (Screen Mesh)

+	+	+	+	-
30	60	90	150	150

STAMPING

Shafts (2)

Crushers (6)

Concentrate residue

(13) Concentrate residue

CYANIDING AND SULPHIDE TREATMENT

Sand Treatment — Cyaniding.

" " Sulphide post treatment

Zinc extractor boxes for gold by Cyanide Treatment.

Copper " " " " Sulphide "

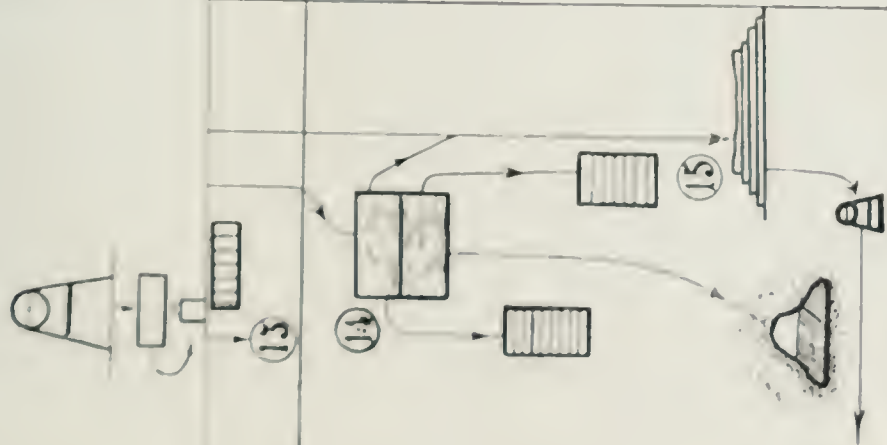
(14) Sand Charge

(15) Combined Slime

Slime to Slime conserving dam.

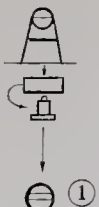
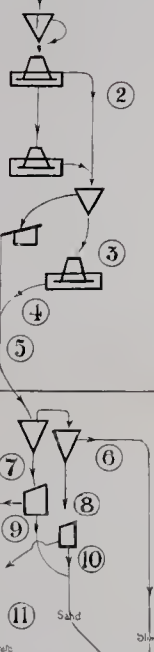
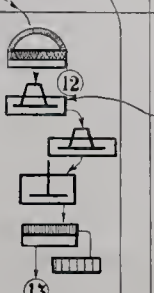
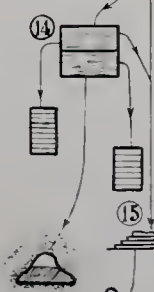
Sand Residue to underground sand filling

Water return pumps.



FW/C.R.

PRESTEA FLOW SHEET.

FLOW	DESCRIPTION	GRADING <small>(Screen mesh)</small>				
		+30	+60	+90	+150	-150
	STAMPING Shafts (2) Crushers (6) Stamps, 110; 1200 lb. weight Stamp duty, 9.5; Screen, 10 linear mesh. $\frac{\text{water}}{\text{solid}} \text{ ratio} = \frac{9}{7}$					
	(1) Automatic Head Sample	24	22	12	7	35
	REGROUNDING AND AMALGAMATING. Spitzkasten (18 double) Cobbe-Middleton Grinding Pans (15, 5ft diameter) (2) Cobbe-Middleton Pan discharge (30 linear mesh screen) Duty per pan = 8.2 tons of -60 per diem = 5.7 " " -90 " " Cobbe-Middleton pan(1) for amalgamating concentrate from 15 grinding pans. Launder Classifiers. Amalgamating Plates and Blankets (21) (3) Biglow feed Biglow Amalgamating and Regrinding Pans (3, 5ft dia) Duty = 10.4 tons -60 per diem. 7.9 " " -90 " " (4) Biglow Discharge. (5) Amalgamation Tail	4	38	16	8	34
	(3) Biglow feed	2	50	15	6	20
	(4) Biglow Discharge.	1	34	23	12	30
	(5) Amalgamation Tail	4	33	17	9	37
	CONCENTRATION. Spitzlufften (22 double) (6) Spitz Overflow (7) Wilfleys (26) Coarse feed. (8) Wilfleys (8) Fine feed Combined Concentrate Tail (9) Wilfley Tail (coarse) (10) Wilfley Tail (fine) (11) Concentrate	6	52	19	8	15
	CONCENTRATE TREATMENT Edward's Simplex Roaster (2) Hearth, 70ft x 6'6" Capacity, 12-15 tons per diem (12) Concentrate after roasting (67% weight of raw) Biglow Amalgamating and Grinding Pans (2) Cyanide solution added Biglow Amalgamating and Grinding Pans (2) Agitators for Cyanide Treatment Dente Filter Press (13) Concentrate Residue					
	(13) Concentrate Residue				2	27 71
	CYANIDING AND SULPHIDE TREATMENT Sand Treatment — Cyaniding. " " Sulphide post treatment Zinc extractor boxes for gold by Cyanide Treatment Copper " " " " Sulphide " (14) Sand Charge (15) Combined Slime Slime to Slime conserving dam. Sand Residue to underground sand filling Water return pumps.	4	39	19	12	28
	(15) Combined Slime				+200 10	+200 90

DISTRIBUTION OF RECOVERY. TABLE I.

	Dwt. per ton of original ore value.	Per cent. of original ore value.	Per cent. of total Recovery.
Recovery by pan amalgamation (raw) } C-M Pans 11.13% } Biglow .. 10.82% }	2.07	21.95	25.59
.. .. pan amalgamation (roasted) ...	0.69	7.32	8.52
.. .. plate amalgamation and blankets	3.43	36.37	42.40
Recovery by amalgamation (total)	6.19	65.64	76.51
Recovery by cyaniding (sand)	0.76	8.06	9.39
.. .. (concentrate)	0.78	8.27	9.65
(Total)	1.54	16.33	19.04
Recovery by sulphide treatment	0.36	3.82	4.45
Total	8.09	85.79	100.00

DISTRIBUTION OF DISCHARGE. TABLE II.

	Per cent. of total tonnage.	Dwt. per ton original ore value.	Per cent. of original ore value.
Slime (discharged to conserving dams) 22.3% at 2.11 dwts.	22.3	0.47	4.98
Concentrate residue (2.1%, at 4.47 dwts.) ...	2.1	0.09	0.96
Sand residue (75.6%, at 1.03 dwt.)	75.6	0.78	8.27
Total Discharge	100.0	1.34	14.21
Total Recovery		8.09	85.79
(Computed Ore Value) Total		9.43	100.00

GRINDING—This operation in the first stage was conducted with a two-fold purpose, namely, to further comminute the ore and to concentrate a high grade product containing coarse free gold. Grinding pans were also employed for regrinding concentrate derived from the first stage pans and from classifiers, concurrently with amalgamation of this concentrate.

The Cobbe-Middleton pans used were well designed for grinding, especially as they automatically maintained the two grinding surfaces within effective distance. These consisted of the shoes attached to the revolving miller and the dies forming the false bottom of the pan, and were kept in working position by means of levers and weights. Having a low discharge with a screen of considerable dimension this type of pan is purely for grinding, and is not easily adaptable for amalgamation. These two functions are not compatible in the same machine unless capacity is to be ignored.

Low grinding capacity per unit was an objectionable feature of both types of pans used. Grinding duty with the C-M pan was only

8.2 tons of —60 mesh product produced per diem, or

5.7 tons of —90 mesh product produced per diem.

Grinding efficiency in terms of —90 mesh produced per horse power consumed was 1.14 tons. This compares with current Rand tube mill efficiency of 1.25 tons on an ore of at least equal hardness.

Mechanical breakdowns were rare, and excellent facilities for rapid dismantling were a feature of the design of this pan. Modifications were planned with the object of providing the body with an overflow and return Spitz, so as to retain the coarse sand until ground and to eliminate the constantly choking screen. The Biglow type of pan was deeper, had classifier attached, and for this reason proved more satisfactory for fine work, especially for amalgamation.

A serious objection to the pans was the large quantity of scrap shoes and dies formed. To avoid breakage of driving gear it was not safe to run them to a diminishing stage. The abrasive wear in the grinding was in itself excessive. Including wastage, wear of shoes and dies amounted to approximately 90 lb. per ton milled, or five times that experienced with similar grinding feed in Rand tube mill practice, using semi-cast steel liners.

AMALGAMATION.—Plate amalgamation was credited with the largest percentage of the total gold recovery. This was supplemented by recovery from blanket concentrate. With the presence of the arsenical sulphide in the pulp, the amalgam surface of the plates would become spotted with the characteristic brown stain and begin to scour. Varying with the quantity of this mineral, plate amalgamation would be affected and frequently the amalgam "sickened," surface tension altered, and as it was disinclined to wet the plate, the pulp flow scoured it off in the course of a few hours. The use of chemicals applied as an antidote proved inefficacious. The tendency therefore was toward the substitution of blankets for a plate amalgamating surface which refused to remain stable.

Amalgamation in grinding pans was an important feature with this ore, and experience led to a considerable respect for its dependability. The objectionable feature was a certain flouing of mercury and amalgam and the danger of discharging collected amalgam when the pulp was allowed to become too dense. Invariably under practical and continuous operating conditions amalgam and mercury were discharged with the pulp and were traced to special traps placed for the purpose. The Wilfley tables acted as an excellent and final trap. In fact mercury gently moving forward in the riffles, amalgamated with any free gold which had escaped the previous traps laid for it.

By giving greater attention to amalgamation in the pans, and by dealing with a large quantity of enriched material total amalgamation increased. Base amalgam was not uncommon and required special refining.

Amalgamation tests were carried out on some 50 selected mine samples for the purpose of ascertaining if possible the variation in ore characteristics in different sections of the mine. It was found that with either clean or graphitic ore the percentage of gold

amalgamable remained low on an assay value of 7 dwts. or less; above this value it rose rapidly. The graphitic schist formation adjoining the walls of the lode contained a high percentage of mineral sulphide of low gold content. The schist being of an oily nature had the distinct effect of dividing mercury.

Pan amalgamation in a cyanide solution was practiced as a step in the recovery of gold from the roasted concentrate. The two pans used were grinding and amalgamating and were placed in series. Mercury was only added to the first, thus employing the second more as a settler.

CONCENTRATE TREATMENT.—An analysis of the raw concentrate is here given:—

Cu	...	...	...	...	trace
As	...	...	...	...	4.68
Sb	...	...	...	...	0.55
Fe	...	...	...	...	22.26
Zn	...	...	...	...	1.50
S	...	...	...	...	19.52
SiO ₂	...	...	...	...	46.50

Considerable coarse sand classed as middlings was included in the concentrate to facilitate roasting mechanically and to secure a better extraction from a high-grade material. The amount taken for roasting varied according to the capacity of the concentrate treatment equipment.

The roasting furnaces were of the Edwards simplex type, i.e., only one row of rabbles along the straight line hearth.

The rabbles in the sulphur burning and the finishing zones were water cooled. They became brittle after being exposed to the heat and gases for some time; a certain amount of ferrous sulphide probably was formed, weakening the crystallisation of the cast iron. Consequently they broke easily and from the slightest jar or strain. The replacement of a broken rabble involved partial cooling of the furnace and was an extremely hot and unpleasant task. Only one fire box, and this placed at the discharge end, was necessary as the concentrate was partly self-roasting.

Push conveyors were in general use for transferring the hot ore from the furnaces to the treatment plant. Considering the glowing and dusty material which they handled they were wonderfully dependable.

Calcination was carried to practically a dead roast. Charging the damp concentrate at the coolest point of the hearth, near the stack, it was gradually moved forward by the tines of the revolving rabbles in a path

of interrupted circles. The first 20 feet of the hearth was taken up in expelling moisture and heating the pyrite to the dissociation point; for the next 20 feet oxidation of the FeS_2 and the arsenic and antimony sulphide minerals proceeded rapidly and the fumes were plainly visible through the observation and air supply doors. As it approached the discharge, at a point of greatest heat from the fire-box, the roasting mass changed from a cherry red to a bright red and the less volatile sulphates passed off. To prevent sintering an excessive temperature was to be avoided, and for this purpose the presence of the considerable portion of silica proved of assistance. Volatilised arsenic in the form of white arsenious oxide was condensed in considerable quantity in the flues of the furnace.

The roasting was generally controlled by observation and by bottle agitation tests of the roasted concentrate with cyanide solution; the completeness of the roast being judged by the degree of cyanide consumption in the test. Carbonaceous schist was oxidised and partly consumed in the furnace and lost its precipitating property.

Regrinding the roasted concentrate was necessary to secure the maximum extraction of the gold, which averaged 95 per cent. The zinc shavings in the first compartment of the concentrate solution extractor box were often replaced by a rich golden deposit from the valuable effluents of the Delme press.

SAND TREATMENT.—The classified sand was given a simple cyanide leaching. Aside from premature precipitation of a portion of the dissolved gold by the graphitic schist, no chemical difficulty was encountered in this treatment. Extraction fluctuated with the nature of the ore, but was always low, the average being in the neighbourhood of 40 per cent. The coarseness of the sand was partly responsible for this.

The problem of the premature precipitation engaged the special attention of the management and technical staff. In the paper referred to the writer enters fully into the development of a post treatment for the recovery of the prematurely precipitated gold. For this reason the subject will only be dealt with here in outline. To quote from the paper:—

"The first positive light on the solution of the problem was the discovery in 1914, by W. R. Feldtmann, that gold precipitated by charcoal or by West African

carbonaceous schist was soluble in a solution of an alkaline monosulphide, for commercial reasons, preferably sodium sulphide. Experiments on Prestea ore at once established the applicability of the discovery."

The writer had the pleasure of the development of this process. It was found that Na_2S added to the ordinary working cyanide solution held the gold in solution. Sufficient had to be provided to precipitate the zinc from the working cyanide solution as ZnS and a slight excess for other secondary reactions and for the one desired. If this excess was not well balanced, the reducing action of the alkaline sulphide in regard to gold dissolution began to function. The method was therefore discarded for the simpler one of a post treatment with Na_2S and precipitating the gold so dissolved separately by means of copper shavings. Not all of the carbon precipitated gold was dissolved by this solvent; experiments established that from 70 to 75% was soluble. The amount actually recovered in the sand treatment was 0.47 dwt. per ton, equivalent to 0.36 dwt. per ton milled.

INVESTIGATION AND MODIFICATIONS.—Investigations into the merits of finer grinding, a return circuit, and preferential pan amalgamation and closer concentration, in conjunction with cyanide and sodium sulphide treatment for slime, were conducted with an experimental unit capable of dealing with the pulp from five stamps. It was found that a marked improvement in total extraction resulted and the slime ratio increased greatly. The substitution of tube mills for pans in purely grinding operations was indicated. Simplification in amalgamation was also considered practicable.

In the slime trials it was found that of the gold extracted one-third was in cyanide solution and two-thirds in the sulphide solution. With accumulated slime the ratio of extraction by Na_2S was much less. It appeared therefore that oxidation due to weathering had affected the precipitating power of carbonaceous schist. In filtering the slime by means of a vacuum filter a peculiar feature was disclosed. After a few days' operation graphitic scales formed on the surface of the filter cloth in sufficient mass to seriously impede filtration. Scrubbing was necessary to dislodge them and restore the filter to normal permeability.

The modifications, coupled with the treatment of the slime outlined here, indicated a possible increase of extraction to 91 per

cent. The exigencies of war, however, precluded their adoption "in toto" at the time.

The Prestea Company is to be credited with a commendable perseverance in maintaining sustained metallurgical investigations which were fostered and supported through the progressive spirit and sympathy of the Consulting Engineer, Mr. H. F. Marriott, and the Manager, the late Mr. W. Crosley.

Prof. G. A. Watermeyer said he must ask those present to pass a very hearty vote of thanks to their president for the exceedingly interesting and careful preparation of his subject. What struck one was that though the ore treated was what they considered very high grade, evidently the difficulties of obtaining extraction were extensive.

Mr. J. Hayward Johnson had much pleasure in seconding the vote of thanks to the president for his very able paper. He was sure the interest it would arouse would be of great benefit, more especially to those members who had to treat refractory ores in other parts of South Africa. They, on the Rand, were apt to pat themselves on the back thinking they knew everything

about gold extraction, but he thought quite a few of them who had been into the outside districts had come up against nasty snags. The paper would be of considerable assistance to anybody treating ores of a similar nature to that described.

Mr. H. R. S. Wilkes, while agreeing entirely with the vote of thanks to the president for his paper, said he would like to ask one question with regard to it, which seemed to strike him as being somewhat pertinent, namely, what was the reason for using cyanide solution with mercury, and was there any appreciable loss of mercury by using cyanide solution?

The President, in reply, said the principal reason was on account of the advantage of commencing extraction as soon as possible. The treatment of the concentrate was rather short and, instead of adding water to the pans, which would have to be eliminated again by some settling or filtering means, the solution was added to the hot, dry mass. It may have been responsible for a certain amount of extra cyanide and mercury consumption, but undoubtedly it simplified the treatment and the plant required

NOTES ON THE MANIPULATION OF OSMIRIDIUM CONCENTRATE.

By R. A. COOPER.

As a number of assayers and others now handle osmiridium in the ordinary course of their duties it has been thought advisable to publish a note warning anyone concerned of the danger of coming in contact with vapours of the volatile compounds of osmium and ruthenium.

Roseoe states that "Osmium undergoes oxidation somewhat readily when finely divided, being oxidised and volatilised when heated in air below 212° and in oxygen below 170° , but not below 155° .

"When strongly heated in air, oxidation of the compact metal also takes place, and this operation is attended with great danger owing to the formation of the highly poisonous tetroxide. Deville in this manner was rendered almost blind for 24 hours by having accidentally become exposed to the vapour of tetroxide. This substance produces the most violent pain and inflammation of the conjunctiva, and vision is permanently injured by the subsequent reduction of a film of metallic osmium.

"The tetroxide has a most powerful penetrating smell, somewhat analagous to that of chlorine and iodine. A very small quantity of vapour mixed with air attacks the lungs, giving rise to very serious inflammation of the mucous membrane. As an antidote to these effects Claus recommends the inhalation of sulphuretted hydrogen, which, however, must be cautiously employed.

"Osmium tetroxide also acts violently on the skin, causing a painful eruption which can be removed by the use of sulphur baths."

Sir William Crookes says that "... the deleterious effects of this body (osmium tetroxide) upon the lungs have not been exaggerated, and too much care cannot be taken to avoid inhaling it."

Ruthenium tetroxide is not readily formed from the metal by heating in air, but may be formed by the action of chlorine on solutions of potassium or sodium ruthenate prepared by fusing the metal with sodium peroxide, etc.

It is stated to be formed also when chlorates are added to acid solutions or when concentrated aqua regia solutions are boiled.

The tetroxide distils readily from heated solutions when proper conditions obtain.

The ruthenium tetroxide vapour has a yellow or reddish colour and an irritating odour resembling that of ozone or nitrous fumes. According to Gutbier and Ransohoff it does not attack the mucous membrane, but cannot long be endured, and may produce severe symptoms of poisoning.

There should not ordinarily be any need for an assayer to heat osmiridium concentrates in the air, but if any such need arises the operation must be carried out in a very well ventilated fume cupboard discharging all vapours to the outside air. The osmiridium concentrates obtained on the Witwatersrand are slightly but distinctly soluble in even somewhat dilute aqua regia, and the osmium contents of such a solution are readily expelled as osmium tetroxide by even moderate heating.

When concentrates, after panning and nitric acid treatment to remove the heavy arsenic, nickel, vanadium, chromium minerals, etc., are being treated with aqua regia to remove most of the gold, the acid should be very dilute and cold. It is never advisable to hold the face over the container, and it is necessary to conduct the operation in fume cupboards. Aqua regia attack should never be carried to extremes when cleaning up concentrates, as, apart from danger of dissolving osmium there is no clear-cut limit to the action of the acid. Gold is certainly dissolved the most readily by weak—say 10%—aqua regia, but as soon as a large proportion of the gold has dissolved, action takes place on the platinum and rhodium. Apparently the latter two metals exist in these concentrates in the form of an independent alloy as they dissolve together.

Concentration of the acid by evaporation at this stage results in the solution of appreciable amounts of iridium, osmium, and ruthenium. Unfortunately any of these rarer metals dissolved are liable to be lost as their recovery is not always possible to the assayer. The aqua regia solutions should always be evaporated to low bulk by steam, diluted somewhat, and treated with a considerable quantity of ammonium chloride to precipitate the platinum and iridium. After 24 hours the precipitate is filtered off and washed with a fairly strong solution of ammonium chloride and ignited to obtain the

metals, while the filtrate is diluted and treated with sodium sulphite to recover the gold. It appears to be advisable generally to leave about 1% of gold with the "osmiridium" to avoid dissolving much platinum, etc.

While discussing osmiridium it may be of interest to note that any estimate of the osmiridium content of a sample, based on the weight of the material left undissolved when the gold beads obtained by ordinary methods of assay are dissolved in dilute aqua regia, is liable to be misleading.

When a fusion is poured from the crucible, metals of the platinum group are all liable to be left to some degree adhering to the crucible, as they are not all alloyed with the lead but only held mechanically by it.

Hammering the lead button is another source of loss, while the changes during cupellation do not appear to have been investigated quantitatively. It would be natural to assume that osmium and possibly some ruthenium is volatilised during cupellation, but it is doubtful whether this is the case.

I have taken 0.1 gm. portions of the granular osmium + iridium + ruthenium metal free from gold, platinum and rhodium, and cupelled with silver, parted with nitric acid—warmed with dilute aqua regia—filtered off insoluble metals, ignited and weighed them. One such series gave the weights 0.138, 0.141, 0.140, and 0.131 gm. after this treatment; an average gain in weight of 37.5% due to oxidation of the metals. Very prolonged treatment with hydrogen at a high temperature was required to reduce the material to approximately its original weight.

With such material as Witwatersrand black sands (heavy sulphides, etc.) it is advisable to take a large portion of the sample—say 500 grams—dissolve all sulphides, etc., by feeding gradually into nitric acid, wash the residue well with water, and decompose silicates by hydrofluoric acid followed by hydrochloric acid.

There remains a small quantity of very heavy material, largely vanadium and chromium compounds, which is undecomposed by these reagents, and also a white powder, possibly diamond dust, which latter cannot be removed by fusion either with alkaline carbonates or with bisulphates. These materials are best removed by very careful washing from beaker to beaker by a

fine jet of water until all "osmiridium" is separated from base minerals.

Mr. H. R. Adam said he had a very pleasant duty to perform in proposing a vote of thanks to Mr. Cooper for his intensely interesting note. It was very interesting to hear that work on these very rare compounds was being carried out here at all. Mr. Cooper evidently, in raising a warning, seemed to think others were going to manipulate them, and on that account he thought there was only one thing the author could do—that was, to give them much fuller information on what he had done in the matter, and he hoped it would come along soon. Mr. Cooper certainly must have a considerable store of new information on the subject, and, if they looked at the names quoted in his paper of the other people who had been working on these compounds—people like Crookes and Roscoe—they could congratulate themselves on the fact that they here were doing work on such subjects. He was not prepared to discuss the paper from the scientific aspect at the moment, but he had very much pleasure in proposing a hearty vote of thanks to Mr. Cooper.

Mr. H. R. S. Wilkes remarked that when the question of osmiridium was first publicly mooted many assayers, like himself, naturally wanted to get all the data they possibly could. He had had the privilege of reading a circular issued by the Tasmanian Government on osmiridium. Naturally he read it with avidity, but found absolutely no information in it useful to them, with an occurrence of iridosmine such as they have here. It spoke of Point iridium which he believed was the great speciality in Tasmania, but he could find no possible information as to the most economical way, or, in fact, any practical way, of separating osmiridium from the Rand ore. He spent some few months on one of the central mines and received from time to time from the smelter small quantities of concentrates recovered from black sands which were described as platinum and iridium concentrates. He treated small quantities to endeavour to obtain as pure an osmiridium product as possible. A preliminary muffle roasting at a low temperature to oxidise the pyrites always gave off a very offensive vapour which he now knew to be osmium tetroxide. Fortunately he always took the precaution of isolating the roast till it cooled or he might have been among the number of the unfortunates attacked with eye and

lung trouble, and he thought that if only for the warning Mr. Cooper had given them his paper was of great value. It appeared to him that there was very little knowledge at all on the treatment or metallurgy of Osmiridium as they found it in the ore here, and it was exceedingly refreshing to find they had a gentleman among them who was able to give them information which, anyway, speaking personally, was quite new, and which could not be found in any textbook he knew of, and which gave them some sort of a practical basis to work on. He sincerely trusted Mr. Cooper would elaborate some safe and complete method as far as he could, and that he would give them the benefit of it so that they might know how to treat osmiridium as they found it here. He was sure every assayer in the country would look upon Mr. Cooper as a benefactor. He had great pleasure in seconding the vote of thanks.

Mr. Jas. Gray, in supporting the vote of thanks to Mr. Cooper, thought the note might also go before the Safety First Committee, presenting as it did a further example of occupational disease.

He would like to associate himself with the remarks of the other speakers with regard to the desirability of further information being published on the subject, especially from the analytical point of view. Mr. Cooper had brought matters relating to these concentrates before their notice on a previous occasion, and he would be extremely pleased if some information about the analytical methods which should be adopted in carrying out investigations on the concentrate were given for the benefit of those interested. Whenever he had had occasion to examine the analytical literature relating to metals contained in these concentrates he had been absolutely bewildered by the variety of methods suggested. He hoped Mr. Cooper would complete his contributions on the subject by adding a third on the methods of analysis of this osmium and iridium concentrate as obtained on the Witwatersrand, and he personally hoped this would be forthcoming at a very early date.

NOTES ON TECHNICAL METHODS OF ANALYSIS: SOME NOTES ON REACTIONS OF THE XANTHATES.

By A. WHITBY and J. P. BEARDWOOD.

(Printed in *Journal*, May, 1921.)

REPLY TO DISCUSSION.

Mr. A. Whitby: In the ordinary way there is really nothing to reply to. It is possibly because we did not invite destructive criticism. It is an unfortunate fact that this is the portion dealt out to many chemistry papers read before this Society by younger members. I think all contributions which embody certain elements of truth should be welcomed and not discouraged. The only remark savouring of criticism comes from Mr. F. W. Watson, in which he questions the solubility of ferric arsenate. Now we have examined quite a number of these ores carrying cobalt and sometimes nickel by Low's method, and have invariably found the arsenic and iron in the ammoniacal solution; not in small amounts but in quantity. The only authority dealing with this is Comey. He describes two ferric arsenates, the normal and the acid salt. The former is stated to be soluble in ammonia when freshly precipitated, and the latter is soluble in ammonium arsenate, other ammonium salts and ammonia.

There is one little correction, or rather an omission, in the note on xanthates. In giving an outline of a method for dealing with these complex ores it is recommended to dissolve in aqua regia, but it is evident that the nitric acid must be subsequently removed by evaporation to dryness with more hydrochloric if necessary.

A RESUMÉ OF STANDARD METHODS IN SAMPLING, ANALYSIS, AND CLASSIFICATION OF COAL

By A. TREVOR WILLIAMS, M.Sc., B.A.

(Printed in *Journal*, July, 1921.)

DISCUSSION.

Mr. W. Anderson: My criticism on Mr. Williams' paper is directed mainly against the methods chosen by him for the sampling of coal.

A table is given on page 2. This shows a direct relationship between the size of the sample and the largest piece of foreign matter. The table appears to me to be unnecessary.

First, from my experience it is impossible to find or to determine the largest piece of foreign matter in a consignment of coal, unless, of course, the coal has been spread out, and then carefully sorted. Second, the suggested weight of coal to be taken for the sample is not possible in practice, as a sample of 39,000lbs. of coal is unmanageable, unless special apparatus is used, and 90lbs. is inadequate if accuracy is desired.

The author again states on page 2, with regard to the size of the sample, thus:—"It should be assumed that the smallest weight is 1,000lbs. for bulks weighing about 100 tons."

In everyday practice it will be found that 1,000lbs. of coal is unwieldly, and it is questionable if a large quantity of coal like this could be thoroughly mixed, and as mixing is one of the main bases in accurate sampling an unrepresentative sample would probably be the result. I have found that 300lbs. of coal is about the maximum quantity that natives can thoroughly mix by means of a shovel. It has also been shown that a 200 to 300lb. sample accurately represents 50 to 100 tons of coal, but in important instances for great accuracy two samples of 200 to 300lbs. may be taken. This would give a more accurate result than one sample of 1,000lbs.; it could be more effectively mixed, and would also result in a great saving of labour. A recent instance which proved that the 200 to 300lb. sample was accurate: A certain truck containing 40 tons of coal was sampled by a chemist; two days later the same truck was sampled by another one; when the values as a result of these samples were checked, both the moistures and the calorific values agreed exactly. I may state that this is not an isolated instance, as I have known it to occur many times.

The method of taking a sample by means of running a shovel along the bottom of an open truck cannot be regarded as a correct method in practice, because after the truck has been opened the larger pieces of coal fall down the slope on the floor of the truck, leaving the smaller coal on the top and on the slopes, also fine coal and dirt from previous loading will be obtained. The sample therefore could contain an excessive proportion of large coal, which the author previously states should be avoided.

The method of holding a scoop in a stream of coal falling out of a truck does not appear to be correct, in practice it will be

found that the large lumps of coal fall off the shovel and so are lost, an unrepresentative proportion of smalls resulting.

Mine Sampling.—I fail to understand how the method given by Mr. Sinnatt for mine sampling is carried out; in practice it is very rare to find the face of a seam level or flush, in fact in most cases it is very irregular, and to obtain a pillar as described from an irregular face would be difficult, unless the sampler had unlimited time to spend in the taking of one sample. Usually a large number of samples are required, especially in the complete sampling of a mine. It is obvious, therefore, that the sampler would find it very difficult to carry about with him when underground large boxes suitable for this operation, especially when 14 feet seams have to be taken.

In the Appendix.—A description is given of how large unscreened coal is sampled by a method of grading. It states:—"Separate about $\frac{1}{2}$ ton into two heaps, one containing the large the other small, in order to ascertain their respective percentages of weight." It then continues to describe how each heap is treated separately. I fail to understand how a proper grading can be carried out without the use of a screen, and again, as the method is intended for practical use, why double the amount of labour unnecessarily? I may point out that the usual practice carried out here with this particular class of coal is to crush the whole sample, quarter it down in the ordinary way, and then send only one sample to the laboratory. This does away with the two samples as suggested.

Sampling of Large Screened Coal.—Mr. Williams gives the following method for the sampling of this class of coal. "The best plan is by carefully inspecting a consignment of, say, 10 tons, to pick out fairly representative pieces to the extent of about 10%. These pieces should then be broken, and again by a further selection about 10% separated from the bulk. This smaller sample should be further broken and thoroughly mixed, after which a final sample of about 10lbs. can be selected for the laboratory."

I would at once condemn a method of sampling which relies on picking or discriminating while taking a sample. It is plain that the human element becomes a factor by this method, and two samplers, if oppositely influenced by their personal interests could easily obtain widely differing values. The inaccuracies of the method are

continued in the reducing, for it states that the sample must be reduced by a process of selection. I therefore cannot see, in view of the obvious inaccuracies that may be introduced, how the method can be recommended as a practical means of ascertaining the value of coal.

Grading the Sample.—A table is given on page 17 which shows the sizes that the laboratory sample must be divided into to obtain correct results. The author states that the ordinary method of mixing a 20lb. laboratory sample does not give a true result. He says: "It is quite impossible to take the two ground calorimeter samples from any part of the 20lb. head, and be sure that they fairly represent the bulk." To carry out this method of treating the laboratory sample entails about four times the amount of work that the ordinary method of quartering would do.

The principle of breaking up the sample into different sizes is bad, as in the remixing at the end of the process a tremendous amount of extra work is necessary to ensure that the coal has been thoroughly mixed. There is also present the liability that with some operators coal once separated may not again be mixed as in the original sample. It has been my experience that representative samples may be obtained from the original 20lbs. by means of quartering, etc., as described in the standard method. I would feel more sure of obtaining accurate results by using the standard method than the one proposed by Mr. Williams, as owing to its simplicity there is less likelihood of making a mistake; with the additional knowledge that the sample has probably been better mixed.

I have myself separated a sample of about 20lbs. into two portions, reduced each separately by means of the quartering method. The calorific values obtained for each portion were found to agree closely.

To substantiate this I may state that the process is carried out every day on the Rand, and it has been proved that reliable results are obtained from the quartering method without resorting to a more complicated and expensive system, which, in my opinion, is less reliable and has little or nothing to guarantee successful results.

Conclusion. — In designing sampling methods, to be extensively used with little or no instruction, and often by persons not thoroughly acquainted with the principles underlying the operation, it is without

doubt necessary that they should be as nearly fool proof as possible while in conscientious but perhaps inexperienced hands. Complications should be avoided even at the expense of prolonging the operation. Mr. Williams seems to be working on exactly the opposite lines to the practice in this country where simplicity, accuracy, and cheapness are points we give full consideration to when designing either methods or apparatus. It must not be assumed, however, that we sacrifice accuracy to either simplicity or cheapness; all three have equal consideration.

REPLY TO DISCUSSION.

Mr. A. Trevor Williams: In perusing Mr. Braidwood's spirited criticism of my paper it occurred to me to question the nature and character of the spirit, certainly, not a chivalrous or a scientific one could have actuated his attack on the work of trained scientists in the derisive manner he has done.

He refers to his criticism as destructive: he has certainly criticised established methods of sampling and other determinations, and referred to methods of his own which are deemed superior, but are not for publication. Is this fair tilting? Let him bring forward his own methods for counter-criticism. To make assertions and sacrifice the more cultured method of expression does not aid in the search for progress.

I agree that my paper, like many others, has largely been written on other people's experience, and I have ascribed to such their due credit. I have, however, done much work in testing the various methods advocated, and convinced myself of their reliability, and in this conviction found pleasure in collecting the material forming the paper, a work of redundancy probably, in the esteem of Mr. Braidwood.

The methods in vogue in South Africa to determine the commercial value of the various coals have not been questioned, and the paper was written as a résumé of the methods adopted as standards by fuelists in Britain, America and Germany—and from whose works brief extracts were culled, and numerous references made. Records of Mr. Braidwood's investigations and methods were not known or available to me, so nothing of his work has been inserted. This is to be deplored, as evidently from his statements and if he was at liberty to disclose the results of his labours, expert fuelists in general would probably derive much gain.

It would be rash to infer that the many

problems pertinent to the peculiar character of South African coals and their economic utilisation could be completely solved along lines of recent investigations—to which I have appended references—yet these references should be of considerable value in indicating the lines of attack of much work that probably yet remains to be done.

Referring to the nitrogen determination, the elaboration of which point was made an occasion for petty sarcasm by Mr. Braidwood, he apparently cannot understand why, after an ultimate analysis, it is further necessary to make a nitrogen determination. It may be pertinent to point out that in the first stage of a carefully conducted ultimate analysis of coal the figures for C and H only can be deemed as reliable, the gaseous residue is a mixture of O and N. The German fuelist concerns himself less with the total nitrogen present in coal than with that portion of it, usually less than 50% of the total, which is recoverable as bye-product, hence my emphasis of this point. I might state that on the occasions that I have met fuelists in England who have been commissioned to investigate South African coals I have invariably found them impressed with their high nitrogen content.

In Britain as probably in South Africa until recently it was "assumed" that the work on coal by the "simple and effective" methods in use was satisfactory, but since 1919 it has been found that facts differ from these intelligent assumptions.

With regard to the 1,000lbs. sample referred to, of course it must appear large to such as are used to small samples, but it is the weight arrived at after mathematical investigation by Mr. Bailey, an American specialist of wide repute, and if it is an absurdity it is Bailey's, and the onus is on Mr. Braidwood to prove that a lesser amount can be representative of the bulk.

In regard to reduction of sample the Thomas apparatus referred to will no doubt prove quite effective for quartering—the important point of mixing so that the sample is representative of the whole is not so clear.

As Mr. Sinnatt, out of his wider experience as Director of the Lancashire and Cheshire Coal Owner's Research Laboratory, is better able to answer Mr. Braidwood's criticism of this part of my paper, it was referred to him for a reply. This Mr. Sinnatt has kindly done, and his contribution is attached.

Meanwhile as one having met a few fellow research men and studied the views of

others I feel sure they will welcome the publication by Mr. Braidwood of his methods of "Sampling and Analysing Coals," which, as he states, gives "marvellously accurate results at a minimum of labour and expense, etc., saving time and reducing apparatus without sacrificing accuracy," all of which is much desired.

In conclusion I thank Mr. Braidwood for stirring up interest in the subject of my paper.

Mr. F. S. Sinnatt, M.B.E., M.Sc.(Tech), F.I.C., M.I.Min.E.: In the course of his remarks on Mr. Trevor Williams' admirable paper on "A Resumé of Standard Methods of Sampling, Analysis and Classification of Coal" Mr. J. Q. Braidwood makes a number of criticisms on work carried out by myself. He evidently has not read my papers or bulletins, and bases his remarks upon the brief extracts given by Mr. Trevor Williams. The paper by Mr. Trevor Williams was, of course, a resumé of the subject, and fuller extracts of the various features of his review would have been out of place where the matter was being dealt with on broad lines.

Mr. Braidwood's remarks are in the nature of destructive criticism, and are not supported by constructive research work. In view of the fact that certain of his criticisms would be modified if he had read the original papers the following additions to Mr. Trevor Williams' papers are given and where possible the remarks of Mr. Braidwood are dealt with:—

Mr. Braidwood states that because I remarked that a sample must contain the proper proportion of small and large coal and small and large impurities it is inferred that small coal is inferior in calorific value. No such inference could possibly be drawn from my remarks, and it is common knowledge that with certain seams the fines are better than the coarse material. The object of sampling is, however, to obtain a sample which is representative of the whole, whether large or small coal or large or small impurities. Mr. Braidwood's humorous and caustic comments on the subject of the 39,000lb. sample, as he will admit, are quite absurd and misleading to the industry, and prove that he has failed to read or appreciate the classical paper by Bailey on Sampling, who gives the figure 39,000lbs. in order to indicate on theoretical grounds what a great weight the sample must be if the pieces of impurity present

exceed a certain weight. The figure (39,000lbs.) is, of course, only part of the table worked out by Bailey to show the relationship existing between the weight of the sample and the size of the individual pieces of impurity so that the error in sampling should be reduced to a minimum.

Mr. Braidwood next attacks the method I have adopted for carrying out investigations of seams of coal. The method consists of cutting a pillar of coal from the seam and having it transported to the laboratory. In describing this process I state that the sample only "represents" a seam of coal and that a pillar should be obtained whenever a visible change in the "seam" occurs. I add (in the Bulletin on Sampling), however, that "the results obtained by the analysis of such samples combined with routine analyses of the output, enable the colliery to keep a complete check on the process of purification of the coal and on the complaints of consumers."

Mr. Braidwood will see, therefore, that the examination of the seam is quite distinct from the valuation of the output of a coal mine.

Mr. Braidwood states that this method of examination is the "most unpractical and unnecessarily expensive method of sampling a seam that I should think it would be possible to imagine," and I think in making these remarks that he passes the bounds of fair criticism, especially when the quotation from my bulletin was incomplete and he evidently had not read it in the original.

The experience gained by me may, however, be of value to many collieries in South Africa, and the following additional details are submitted:—

According to a number of returns the cost of such pillars of coal varies from £1 to £3. A good collier can easily obtain such a section in a shift, and it is usually sent up with the ordinary coal in a box packed in fine coal. Over twenty seams have been and are being examined at intervals in this manner, and the examination will continue. The importance of such an examination cannot be entered into in detail here, but in the writer's opinion it is the only manner in which a seam can be investigated, and as will be gathered the cost attached to obtaining such a sample is a relatively small item.

It may be added that the writer is at present carrying out an investigation upon a seam of coal sent from South Africa to the home country for examination.

At a later stage Mr. Braidwood states that he does not agree that a sample weighing 40lbs. should be sent to the laboratory. No suggestion that a sample weighing 40lbs. should be kept is made, but it is considered that it is advisable that the chemist concerned, with the analysis of the coal should have the opportunity of carrying out or supervising the final stages of the sampling process. In the paper by Bailey it is shown on mathematical grounds that the size of the particles during sampling are a direct function of its weight, and if the sample falls below 40lbs. in weight the size of the particles should be so small that it is troublesome to carry out the final stages of the sampling process at the point where the sample is obtained. Before the final weight of about 1lb. is obtained the material should have been crushed so that it would pass through a sieve of about 8 meshes to the linear inch.

Mr. Braidwood states next that the agglutinating curve which he designates "hit-or-miss" does not commend itself to him. It is evident that Mr. Braidwood attaches very little importance to the agglutinating power of coal. In the light of modern methods of carbonisation and combustion of coal the agglutinating power appears to be a characteristic of coal of the most vital importance, and although the method of measuring the caking power is only accurate to about one unit it, nevertheless, places in the hands of the user values of the very greatest technical interest. Mr. Braidwood is no doubt well aware that the greatest importance is attached to this value both on the Continent and in the Home Country.

He further adds the following: "I think we might devise a better method if we had the money and time to spend on research that the people at Home seem to have." The writer hopes that these opportunities will be given to Mr. Braidwood in the near future, as such a method of determining the agglutinating value as he says he could devise would be of the greatest value to industry throughout the world. As to the cost of carrying out the research, in one coal field it works out at about one-fiftieth (1/50) of a penny per ton of coal raised in the field, which Mr. Braidwood will surely not consider an unreasonable charge for scientific research.

The writer hopes soon to hear that the galleries in South Africa have joined together and organised a research association

to enquire into the properties of South African coals. From the experience the writer has gained of the coals of South Africa it would appear that they possess special properties, and as the writer understands that they are being placed on the world's markets a knowledge of their chemical properties, including the agglutinating properties, becomes of the greatest importance to the coal field of South Africa and the industrial world in general.

THE ACIDITY OF MINE WATERS.

By F. W. WATSON and R. A. COOPER.

(Printed in *Journal*, September, 1921.)

DISCUSSION.

Dr. J. Moir: The particular importance of this valuable investigation lies in the demonstration of the order in which the acidic impurities of mine water are precipitated by alkali. If the Reef had consisted entirely of quartz with the usual proportion of pyrites, all mine waters would have been very acid, yet the problem of neutralising them would have been very easy, since only two ingredients (iron sulphate and free acid) would have required attention. In reality the free sulphuric acid has been imperfectly converted into salts of lime, magnesia, alumina, manganese, and sodium, and the problem is quite complicated.

In my opinion, however, the problem of corrosion of iron and other metals underground does not wholly depend on acidity, but in part depends on direct action of ferric sulphate (without acid) on metallic iron. Some experiments I did for the Engineers' Society about 1904 seemed to show that the acidity required to corrode iron rapidly is much higher than the acidity of any mine water. The authors would do a good service to the mining industry if they would reinvestigate this point by comparing the action of mine water on different kinds of iron and steel with the action of plain sulphuric acid made to the same hydron concentration as the mine water.

As regards finding the *time-requirement* of a mine water I should like to point out that the new indicator "Bromthymolblue" (British Drug Houses, Ltd) appears to be theoretically perfect for this purpose if used externally on a spot plate. It is more correct than methylred.

COAL PILLAR EXTRACTION FROM TWO SEAMS, AND SURFACE EFFECTS.

By W. T. HESLOP, M.I.M.E., F.G.S.

(Printed in Journal, October, 1921.)

DISCUSSION.

Mr. C. J. Gray: I do not wish to miss this opportunity of saying a word in praise of Mr. Heslop's paper. It describes an excellent example of application of scientific thought and observation to a difficult mining problem. The particular method of working which was finally adopted is applicable only under particular conditions, but the underlying ideas are of much wider importance and may be studied profitably even on the Rand. The main technical ideas appear to be to make the unworked ground protect the working faces and travelling ways, and to encourage the roof to fall elsewhere, while the main economic idea is to get the whole of the workable mineral out at the greatest total profit. Those ideas are far from general practice on the Rand, where, rightly or wrongly, selective mining rules in those mines in which it has left anything worth selecting. At first sight Mr. Heslop's method of working, like the Kimberley method, appears very dangerous, but experience has shown both to be very safe. They illustrate the principle that men guard against obvious dangers, but are caught by those not so obvious: often a naturally safe mine is more dangerous than one which is naturally dangerous.

WASTE ROCK IN ORE MILLED.

By W. A. CALDECOTT, D.Sc.

(Printed in Journal, October, 1921.)

DISCUSSION.

Prof. G. A. Watermeyer: In Dr. Caldecott's paper he gives a fundamental formula expressing the relation between the value of the screen sample, the value of the reef sample, and value of the waste, and apparently deduces from one equation the percentages of reef and waste. This somewhat obscures the logical development as he has failed to express the relation between the percentages of reef and waste in the screen sample which must obviously amount to 100. As it stands there seems to be a

possibility of determining two unknowns from a single equation.

The relations might be more clearly expressed thus:—

Let A_s = Value of Screen Sample.

„ A_r = „ Reef in the mixture of reef and waste.

„ A_w = „ Waste in the mixture of reef and waste.

„ x = percentage of Reef in mixture.

„ $100 - x$ = „ Waste „

Then $100 A_s = x A_r + (100 - x) A_w$

$$x (A_r - A_w) = 100 (A_s - A_w)$$

$$x = \frac{100(A_s - A_w)}{A_r - A_w}$$

SOME NOTES ON THE PILGRIM'S REST GOLDFIELDS.

By H. C. F. BELL.

(Printed in Journal, November, 1921.)

DISCUSSION.

Mr. J. H. A. Diering: As a member of the Pilgrim's Rest mining community I should like to congratulate Mr. Bell on his valuable paper, which embodies the results of much practical field-work and careful study. With regard to details I have a few comments to offer. T. A. Rickard says: "When starting a discussion it is well to begin by defining the terms to be used." The term "leader" as used on these fields has a rather restricted meaning, which might cause misunderstanding if not fully explained. "Leader" locally means any ore body, which cuts across the strata at an angle, unless it assumes such dimensions and irregularity of shape as to be termed a "blow." "Reef" on the other hand is locally practically always understood to mean an inter-bedded ore-body. The term "Thelma Reef" as used by Mr. Bell and others is misleading, and the name "Thelma Series of Leaders" should be substituted for it. In the river section of the Vaalhoek Mine of the T.G.M.E. these Thelma leaders occur in great number over an area of at least 3,000ft. by 500ft. They were formed in the dolomite by impregnation—often extending to complete replacement—and by the filling of fractures, fissures, and caves through deposition from solutions. They thus occur as "leaders," small "blows," and over short distances may even take the form of an inter-bedded reef. Although closely

related to one another genetically they occur as distinct and separate ore-bodies, often without any visible connection between them. There can hardly be any doubt that they owe their origin to the dynamic and thermal agencies at work during and after the formation of the Vaalhoek Dike. The theory advanced by Mr. Bell, that the Thelma leaders were formed by mechanical or chemical transportation of material from overlying inter-bedded reefs is not supported by the available underground disclosures. On the contrary in the river section of the Vaalhoek Mine, where Thelma leaders have been developed and mined for a distance of 3,000ft. on the strike and the overlying Glynn's Reef has been exploited for a distance on the strike of 2,000ft. in workings in close proximity to, and in many places overlapping, Thelma workings, all the available evidence indicates that the two occurrences are in every way independent of each other. The new three compartment shaft recently sunk in this section affords a typical example. Both the Top Reef and 19ft. below it the Glynn's Reef were sunk through and a cross-cut put in 21ft. below the Glynn's Reef disclosed several wide and payable leaders, the first one occurring practically in the shaft itself. The inter-bedded reefs were of very compact structure, did not show the slightest trace of having been subjected to any leaching, and were separated from the leaders by layers of hard, impermeable dolomite. The characteristics of Glynn's Reef and the Thelma leaders are also too different from a purely mineralogical point of view to make the formation of the latter by dissolution and redeposition of material from the former at all probable. To pick out merely one feature in this connection a Thelma leader mined in the Nek Section of the Vaalhoek Mine yielded ore assaying 42% copper, 45oz. silver, and 1oz. gold to the ton. A vast amount of concentration would have to be assumed to trace these values back to the comparatively low copper and silver contents of Glynn's Reef.

With regard to Mr. Woodburn's remarks in the discussion I should like to cite several instances where in more recent years two or more reefs belonging to different horizons have been successfully worked in the same area. Theta Mine worked a payable Shale Reef occurring 350ft. above its two Theta Reefs, which latter were both payable. Theta North Mine had both Bottom Theta

Reef and Beta Reef payable in the same area. On Theta Extension Mine both Theta Reefs are payable. Payable Bottom Theta Reef overlies payable Beta Reef in a large area in Brown's Hill Mine, and workings on a reef in the shales at Columbia Hill Mine overlap Bottom Theta Reef stopes in Peach Tree Mine.

The President, said Mr. Diering had only recently joined the Society, and they therefore appreciated all the more such an excellent contribution to the discussion.

The meeting then terminated.

BOOK REVIEW.

ELEMENTS OF ENGINEERING GEOLOGY, by H. Ries and T. L. Watson. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd. 5½in. by 8½in., 365 pp., 251 illustrations. Price 22s. net.

This book is intended to meet the requirements of those who desire one smaller than "Engineering Geology," by the same authors, and it should succeed in doing so. It deals particularly with those aspects of geology which concern the civil or mining engineer, and it should, by showing the practical bearing of geology, interest many who are not attracted by subjects which appear purely academic. The text is aided greatly by the admirable illustrations, many of which are from photographs by the authors. One slip, through interchange of blocks, appears, however, to have been made, for Fig. 96 given as an anticlinorium is a synclinorium, and Fig. 97 given as a synclinorium is an anticlinorium. From the South African standpoint too large a proportion of the space available has been devoted to control of rivers, wave action and shore currents, and lakes and swamps—fuller treatment of such subjects as underground water and ore deposits would have been appreciated. The chapter on glacial deposits has, however, interest which at first might not be recognised, for much in it applies to the Dwyka tillite which is widespread in South Africa.—(C. J. G.)

Notices and Abstracts of Articles and Papers.

CHEMISTRY

COAL TARS FOR ROAD-BINDING.—The search for the ideal binder for road metal has an interest to the chemist as well as the engineer. The source of the tar determines to a large extent the susceptibility factor—the relative effect of heat on the tar or pitch, the adhesiveness and the viscosity of the road binder manufactured from the tars. The susceptibility factor is a constant to each individual bitumen or pitch from varying sources, and is roughly the ratio between the elasticity and the melting point. No coal tar pitch has a low susceptibility, but some pitches are more satisfactory than others. It is obvious that the binding power of the tar is essentially the result of the susceptibility factor. What is required is a tar which will retain its viscosity under varying temperature conditions.

The chemist can control the factor of free carbon, which increases susceptibility. Naphthalene in excess also seems to act similarly. Phenols should be removed. Oxidation of the pitch takes place in practice, and when complete results in the formation of more free carbon.

A certain amount of free carbon is probably required as it inhibits the decomposing action of the ultra violet rays in sunlight. Various other absorbents for the active rays act as inhibitants. The optimum free carbon allowable appear to be about 7 per cent.—**LATEX.** *The Chemical Trade Journal and Chemical Engineer*, page 624, November 19, 1921. (F.W.)

ELECTROLYTIC ESTIMATION OF GOLD, PALLADIUM AND PLATINUM.—Gold may be electrolytically deposited, rapidly and quantitatively, from solutions of the chloride containing acetate, this method admitting of the separation of gold from copper, palladium and platinum, according to W. H. Treadwell, in *Helv. Chim. Acta*.

The readiness with which palladium is attacked in comparison with platinum, when subjected to anodic polarisation in hydrochloric acid solution, serves as a means for the approximate estimation of the palladium content of a precipitate composed of a large proportion of palladium and little platinum.—W. H. TREADWELL, *Mining and Scientific Press*, from *Helv. Chim. Acta*, 24th September, 1921, page 440. (C.J.G.)

DETERMINATION OF AVAILABLE LIME IN QUICK-LIME AND HYDRATED LIME.—The author defines "available lime" as free or uncombined calcium oxide.

Complete gravimetric analyses were made of high-calcium and high-magnesium quick and hydrated limes, and calcium oxide determinations then made by the seven methods given in detail by R. K. Meade in *Concrete*, Vol. X. (1917), Cement Mill Section, page 25.

After investigation at the Bureau of Standards, the following modified Scaife method is approved by the Interdepartmental Conference on Chemical Lime, and is now being tested in Government and works laboratories:—

The details of the method are as follows:—

Place 1.4 gm. of the finely-ground lime in a 400 c.c. beaker, add 200 c.c. of hot water, cover, heat carefully, and then boil for three minutes.

Cool and titrate with N hydrochloric acid, allowing acid to drop rapidly and stirring very vigorously; phenolphthalein indicator being used.

When the pink colour disappears in streaks, retard the rate of addition of acid, but continue until the pink colour disappears entirely and does not re-appear for one or two seconds. Note the reading and ignore any return of colour.

Now repeat the experiment, substituting for the beaker a one-litre graduated flask carrying a stopper fitted with a short glass tube drawn to a point.

After boiling, cool and add dropwise 5 c.c. less acid than before. Call the number of c.c. used A.

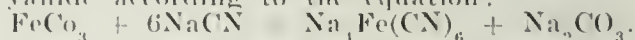
Grind up any small lumps with a glass rod flattened at the end, dilute the solution to the litre mark with freshly boiled distilled water, and shake thoroughly for four or five minutes and allow to settle for thirty minutes.

Pipette off 200 c.c., add phenolphthalein and titrate slowly with 0.5 N hydrochloric acid until the solution remains colourless on standing one minute. Call this additional number of c.c. B. Then the percentage of available CaO = $2A + 5B$.

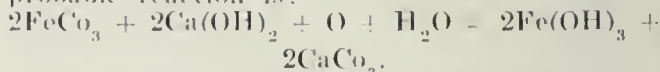
This method in the hands of different operators gave concordant results, agreeing generally to within 0.2% with the figure calculated from the complete analysis. The high-calcium hydrated lime alone among the samples tested gave somewhat lower results than calculated.—A. I. WHITSON, *Chemical and Metallurgical Engineering*, page 740, Vol. 25, No. 16, October 19, 1921. (R.A.C.)

METALLURGY.

LIME CONSUMPTION IN CYANIDATION.—The author describes his experiences at the Vita Grande unit of the American Smelters Securities Co., Parral, Mexico, where the cyanide treatment is accompanied by a high lime consumption. In distinction to the soluble and insoluble sulphates to which the cause of high lime consumption is often ascribed, the cause of this at Veta Grande was found to be due to an appreciable amount of ferrous carbonate (FeCO_3), which was oxidised during the treatment to ferric hydrate. The oxidation was accompanied by a corresponding precipitation of calcium carbonate if lime was present in sufficient quantities, the iron otherwise combining with the cyanide to form sodium ferrocyanide according to the equation:



The formation of sodium carbonate was proved in tests in which caustic soda was used instead of lime. In the presence of lime the probable reaction is:—



The actual lime consumption varies with the time of treatment, but not in proportion, and

decreases as the amount of ferrous iron becomes smaller. Sodium ferrocyanide is not formed in the treatment so long as the lime is present in amount above 0.005 per cent. The solutions at the Vita Grande plant showed no trace of ferrocyanide after being in continuous use for over a year.

The ores under investigation were all from above water level, and were of the following approximate analysis:—

	%
Insoluble	75.00
Ferric iron	3.00
Ferrous iron	2.00
Al ₂ O ₃	4.00
CaO	4.80
Mn.	0.60
Mg.	0.20
Pb.	0.25
Cu.	Trace
Zn.	1.25
Mo.	Trace
Sb.	Trace
S.	0.08

The ore varies from a slightly silicified andesite to nearly pure quartz or calcite, the more highly silicified ore being characterised by a higher iron content and a lighter colour than the predominant surface ores, which are of a deep-red colour, in spite of their relatively low percentage of iron.—RALPH W. PERRY, *Mining and Scientific Press*, 29th October, 1921 p. 645. (C.A.M.)

MINING.

NEW LIQUID-AIR MINE RESCUE APPARATUS.—Before Section G (Engineering) of the British Association at its recent Edinburgh meeting, Professor H. Briggs read a paper describing two new forms of rescue apparatus which had been designed to comply with the most stringent regulations of the Home Office. Particulars were given of a type in which the oxygen was derived from the evaporation of enriched liquid air.

The author described the liquid-air apparatus with the aid of a flow diagram. It was based, he said, upon Blackett's patents of 1910 and 1911, and was the result of prolonged experiment by Messrs. G. L. Brown and F. P. Mills, and of experience gained at the North Midland and the Northumberland and Durham groups of Mine Rescue Stations, of which these workers were respectively the Chief Officer. It was a great improvement upon existing types and he thought it might safely be said that a liquid-air apparatus had now been evolved which was both comfortable and gave a fair guarantee of security to the man wearing it.

The apparatus was demonstrated. The liquid air was poured into the pack, which was carried on the back of the wearer, to which flexible tubes attached to the mouthpiece were carried. The pack consisted of a strong metal can, insulated with magnesia-sabotex, with a stout leather cover. A second metal can, lighter, was carried within the first, there being an air space between the two. The inside can was divided into compartments by a gauze framework, and dry, coloured, asbestos-wood formed into the space. This asbestos-wood

soaked up the liquid air completely, and effectively prevented its escape.

Air evaporating within the pack passed along a tube, into the space between the two cases, and finally into the breathing circuit. This space enabled the air moving through it to gain heat, the rise of temperature being sufficient to prevent the inhaled air being too cold; it also acted as a trap for any liquid which, due to the over-filling of the pack, might escape, and improved the insulation of the pack. It should be noted that the insulation, while being sufficient to avoid too rapid an evaporation of the air, must allow enough heat to pass to boil off an adequate supply for the period of use of the apparatus. When the pack had been freshly charged, the rate of evaporation was high; the volume of cold air circulating in the space between the two cases was at a maximum, and its insulating effect was thus also a maximum. Therefore, at this stage there was a tendency for the air space to effect a reduction in the excessive ebullition of gas, while, when the evaporation was flagging, it was stimulated by an increase in the passage of heat across the air space. The gas which boiled off during filling was allowed to escape through a tube without interfering with the entry of the liquid, so that after charging only one opening had to be closed by a blank screw-cap. The working charge of 4½ to 6 lbs. of liquid air could be put in, and the cap screwed on, in less than a minute.

The breathing circuit consisted mainly of solid-drawn brass tubing 1 in. in diameter. The tubular frame was bent over the shoulders, and extended as a wide collar in front of the chest; from the centre point of this collar hung the breathing bag. This bag consisted of two saucer-shaped pieces of rubber joined at their edges, it could not be entirely flattened by the suction of the lungs, and was very unlikely to be flattened by external pressure. The capacity of the bag was 6 litres (1.32 gal.). The air was directed round the circuit by valves, which resembled those formerly used as inspiratory valves for the box-respirator, with the important difference that the perforated seats were of stout rubber instead of metal. A valve consisted of a disc of thin rubber riveted at its centre to a larger, perforated disc. The valve-boxes were also the couplings between the flexible corrugated tubes connected to the mouthpiece and the tubular frame, and the valve-seats acted as washers in these joints. The resistance of the valve was very low, its slip negligible, and it functioned well in any position. A purifier was placed below the pack, containing a charge of about 11b of caustic soda granules held in carriers of perforated metal, and a relief valve was set to blow off at a pressure of about 3 in. of water column. A low resistance to breathing was a physiological necessity for any rescue apparatus, with the liquid-air apparatus, where the relief valve was between the mouth and the purifier, it became, in addition, a physical necessity. If the resistance of the purifier exceeded the resistance to opening of the relief valve, the exhaled air would pass out of the latter, the apparatus would become depleted of air, and the wearer would be compelled to reduce his rate of exertion or, in an extreme case, to cease using the apparatus. Therefore care

had been taken to bring down the resistance of the circuit, and especially that of the purifier, to a minimum. During the early stage there was such a flash of air vapour from the pack that it passed out to waste, together with the product of respiration exhaust. Later on, however, when the flow from the pack had sunk down, the man could not afford to throw it away, and during that stage the apparatus became a true regenerator—an increasing proportion of the expired air passing through the purifier, and being re-breathed. Taking 5 lbs. of liquid air as a standard charge, and considering the fact that $1\frac{1}{2}$ or 2 lbs. was lost in cooling down a pack in filling, a team of five rescue men needed at least 36 lbs. for a 2 or $2\frac{1}{2}$ -hours spell of work. The apparatus of one team could thus easily be charged from a single 50-lb. container. The appliance was comfortable to wear, eminently safe and serviceable; it had proved highly satisfactory in extracting CO_2 and in supplying a sufficiency of oxygen to the purified air. Also, it was easy to use, there being no locks to turn, no valves to adjust, and no gauges to be read.—H. BURGESS, *I. and C.T.R.*, September 23, 1921, p. 428. (J.A.W.)

VENTILATION DOORS IN ARIZONA COPPER MINES OPERATED BY COMPRESSED AIR.—Only in recent years has the proper ventilation of metal mines received serious consideration. Increasing temperature and humidity with greater depth in some of the larger mines of the West prevented the efficient operation of the mines and made the installation of mechanical ventilation systems necessary. Doors that interfere with tramming are generally needed to control properly the mechanically induced air currents and are one of the inherent disadvantages of the system. In fact, the necessity for the use of doors in the main haulage-ways has discouraged the installation of mechanical ventilation in some metal mines.

A number of mining companies in Arizona are using ventilation doors that can be opened and shut mechanically by the motorman without leaving his motor or stopping his train. The Copper Queen Branch of the Phelps-Dodge Corporation at Bisbee, introduced these doors, adapted from those in use in the company's coal mine at Dawson, New Mexico. The doors at the Calumet and Arizona mine in the Bisbee district are representative of those in use. These doors are substantially built in 2-in. lumber, are air tight, well placed and have two openings or passageways. The main door, which is used for the motor trains, is 5ft. wide by 6ft. high, and is opened by compressed air and closed by a counter-weight. At the side of the motor door is the man

door, which is 18in. wide by 5ft. high, and is opened and closed by hand.

The mechanism for opening the main door consists of a section of 5in. pipe about 5ft. 6in. long, threaded at both ends and used as an air cylinder. A piston fits in the cylinder and is attached to a 1in. plunger rod which passes through a stuffing-box at one end of the pipe. The free end of the rod is attached to a rope that goes over a pulley and is fastened to the door. A $\frac{3}{4}$ in. pipe connection from the compressed-air line is tapped into the cylinder at the packing end. When the air is turned on, it forces the piston to the other end of the cylinder and thereby opens the door. The door is held open as long as the air pressure is maintained, and is closed by the counter-weight and the force of the air current when the pressure is released. The air is turned into the cylinder from the main air line through a three-way cock. Levers placed at some distance from and on either side of the door are connected to the air cock by two wires. When a train approaches the door, the motorman reaches out and pulls the first lever; this opens the cock, turns the air into the cylinder, and opens the door. After the train has passed through the door the motorman pulls the lever on the other side, which shuts off the air, releases the pressure in the cylinder and closes the door. The motorman on a train coming from the opposite direction pulls the same levers, but in reverse order. The distance of the levers from the door depends on the length and speed of the trains, but should be long enough to give the motorman time to stop his train before it wrecks the door if the mechanism fails to work. The distance is 150ft. at the Calumet and Arizona mine.

A red light is generally placed at each level and other safety precautions are taken. Some doors have been demolished by trains, but with ordinary care on the part of the motorman no accidents should occur. None of the doors have been touched by trains in the Calumet and Arizona mine for a number of years.—E. D. GARDNER, *Mining and Metallurgy* from U.S. Bureau of Mines Reports of Investigations, Serial No. 2273, October, 1921, page 58. (C.J.G.)

CHANGES OF ADDRESS.

STRANGE, E. H., *U/o* San Francisco: Box 569, Stockton, Cal., U.S.A.

COWLES, E. P., *U/o* Johannesburg: Modder Deep Levels, Ltd., P.O. Box 326, Benoni.

BOYDELL, H. C., *U/o* Athens: Dept. of Geology, University of Wisconsin, Madison, Wisconsin, U.S.A.

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No. 9.

Ordinary General Meeting,
March, 1922.

In consequence of the industrial disturbances on the Witwatersrand, which culminated in revolution, necessitating the enforcement of Martial Law regulations, the Council was unable to call the Ordinary Monthly Meeting of the Society in March.

The next Monthly Meeting will be held on Saturday, the 22nd April, 1922.

BOOK REVIEW.

THE METALLURGY OF THE COMMON METALS,
by Leonard S. Austin. Fifth Edition.
1921. Published by Chapman & Hall,
Ltd., 11, Henrietta Street, Covent
Garden, London, and John Wiley &
Sons, New York. (Price, 42s. nett.)

The latest edition of this rather well-known work contains 50 chapters. It deals more with the outline of the processes used in the metallurgical treatment of ores and products than with the fundamental principles involved. As it covers such a wide field, a description of all methods in common use is hardly possible. For instance in the chapter on Fuels, only one type of pulverizer is mentioned, ball mills not being referred to.

In the chapter on Sampling the use of mechanical samplers, such as the Hydram and the Elmore sampler, for cutting pulp streams is not included in the text. The book deals principally with American metallurgical practice. In describing the use and operation of tube mills the reader obtains the impression that flint pebbles are the main grinding media, notwithstanding the fact that on the field where the largest number of tube mills operate, the ore itself supplies the pebbles or grinding medium. Diaphragm cone classifiers are said to be

troublesome and inefficient, whereas on the Witwatersrand district quite the contrary is experienced.

In the section devoted to gold metallurgy certain rather obsolete methods, such as inside mortar box amalgamation; also 1912 Rand practice are referred to. For the students' information it is, of course, fully justified. In describing the Merrill slime press, the illustration of the precipitating press is shown, evidently an error.

The metallurgy of silver is described in a most interesting and instructive way, and should be studied by those who have found the daily practice of recovering gold, monotonous.

An outline of the metallurgy of iron is given, blast furnace, open hearth, Bessemer and electric furnace practice. The recovery of copper which has witnessed such great strides and innovations during the past decade is dealt with fully and brought to date. Particular attention is given to the hydrometallurgy of this metal. The general metallurgy of lead and of zinc is outlined, including a short chapter on wet recovery methods of zinc which came so much to the foreground during the period of the Great War.

The last four chapters deal with the selection of plant sites, accessory equipment, also the economics of metallurgy. Aside from certain broad principles and comparisons little can be written on detailed costs of plants and processes under present chaotic and abnormal industrial conditions.

The illustrations throughout the book are excellent, particularly the reproductions of drawings. The general impression of the subject matter is that there is much compression. As a work of ready reference of modern practice it will undoubtedly have a wide field. In style it is plain and technical details are not involved. It is a book which can be recommended to those who take a general interest in the metallurgy of the common metals. (F. W.)

Notices and Abstracts of Articles and Papers.

CHEMISTRY

A NEW METHOD FOR THE EVALUATION OF ZINC DUST.—One gram of the fine zinc dust is shaken with 20 c.c. of water in a 300 c.c. Erlenmeyer flask, 200 c.c. of sulphuric acid (100 gms. per litre) and 25 c.c. of 3% hydrogen peroxide are then added together, and the whole is allowed to remain with occasional stirring for four to eight minutes. The zinc particles should then be all dissolved, leaving only a loose metallic slime of lead, etc. Twenty c.c. of 40% sulphuric acid are then added, and the excess of hydrogen peroxide estimated by titration with potassium permanganate solution (15 gms. per litre), which has been standardised against sodium oxalate.

For exact results the above quantities and procedure must be strictly adhered to, the solution of the zinc must not take more than ten minutes, and the titration must take place immediately after this. — BULLENHEIMER, *J. Chemical Society*, reprinted from *Metall u Erz.* 1921, 18, 443-446, November, 1921, ii 655. (R.A.C.)

FIRING ASSAY MUFFLES WITH PULVERIZED COAL.—Assay furnaces have been fired with pulverized coal with complete success and economy at a smelter in Utah. The arrangement is as follows:—Back of the furnace a steel bin is hung so that its bottom is level with the top of the furnace. The bin has an open bottom in which is a screw feed made from a 2 in. auger on a shaft provided with variable speed through cone pulleys. The coal drops through a 3 in. garden hose into a funnel, thence into a 3 in. pipe leading into the furnace. The 3 in. pipe is connected with a fan running at high speed. The fan supplies three furnaces. The coal is blown into the furnace and ignites there. When ready to heat up the assayer raises the damper on the stack, places some lighted oil waste in the fire-box, starts the coal feed, and the required heat is quickly obtained.—E. N. HAMILTON, *Mining and Metallurgy*, December, 1921, p. 24. (F.W.)

ESTIMATION OF NITROUS FUMES IN AIR.—A new test for nitrites or nitrous acid is described by J. Moir (*J. S. African Assoc. Anal. Chem.*), which is similar to that of Hosvay, but in which *p*-nitro-aniline and *α*-naphthol are used instead of sulphanilic acid and naphthylamine. Two solutions are required (*a*) consists of a solution of 1.5 grammes of *p*-nitroaniline in 10 c.c. of hydrochloric acid, diluted to 500 c.c.; (*b*) contains 2 grammes *α*-naphthol, 1.1 gramme of sodium hydroxide, and 10 grammes of sodium acetate per 500 c.c. The liquid to be tested for traces of nitrite is mixed with 1 to 10 c.c. of (*a*), heated to 50° C. until diazotisation is complete, after which solution (*b*) is added in the same quantity as (*a*). In the presence of a nitrite an orange-red precipitate of *p*-nitro-benzeneazo-*α*-naphthol is quantitatively obtained. It is collected, after an hour, in a Gooch crucible, dried, and weighed, 293 parts being equivalent to 92 parts of NO₂ or 69 parts of NaNO₂. The dyestuff dissolves in

sodium hydroxide solution, producing an intense bluish-violet coloration, which may be used for a colorimetric estimation.

According to the British Government requirement the fumes from 100 grammes of ignited fuse must not contain more than 0.5 gramme of nitrogen peroxide. To distinguish between this compound and nitrite in smoke use is made of the acidity of the former. The following methods have given satisfactory results:—(1) The gas is kept in contact with neutral hydrogen peroxide solution for twenty-four hours, and the solution then titrated with N/10 sodium hydroxide solution, with methyl orange as indicator ($2\text{NO}_2 + \text{H}_2\text{O}_2 = 2\text{HNO}_3$). It was found as an empirical factor that 1 c.c. of the standard alkali = 0.0060 gramme NO₂. (2) The fumes are treated with a solution of potassium iodide (1 gramme in 20 c.c.) for at least six hours with occasional shaking, during which the walls of the container should be thoroughly wetted, and the liberated iodine is titrated with N/10 thiosulphate solution. One c.c. of the latter is equivalent to 0.0051 gramme of nitrogen peroxide, instead of the theoretical value. — Dr. J. MOIR, *Chemical Trade Journal and Chemical Eng.*, December 31, 1921. (F.W.)

DETECTION OF SACCHARIN IN WINE.—Five hundred c.c. of wine is evaporated to about 250 c.c., the liquor thus dealcoholised is cooled, treated with 5–10 c.c. of dilute sulphuric acid, and extracted with 100 c.c. of ether in the apparatus described by Ledent (*J.*, 1913, 879). The ethereal solution is washed with water, the greater part of the ether removed by distillation, and the remainder by evaporation in a porcelain basin. The dry residue is dissolved in very dilute sodium hydroxide solution, heated on a water-bath, and 5% potassium permanganate added in small quantities at a time until a persistent red coloration is obtained; sulphuric acid is then added, and the mixture again oxidised with permanganate. After the excess of permanganate has been destroyed by the addition of sulphurous acid, the solution is evaporated to about 20 c.c., cooled and extracted three times with ether, using 10 c.c. each time; the ethereal solution is washed with water, evaporated, the residue treated with 3 c.c. of water and again evaporated. This treatment is repeated frequently so that the heating on the water-bath is prolonged for 1 hr. All benzoic acid is thus removed. If the residue then has a sweet taste, the presence of saccharin is indicated, and may be confirmed by using the residue with sodium hydroxide and testing for salicylic acid in the usual way. — C. VON DER HEIDE and W. LOHMAN, *Z. Unters. Nahr. Genussm., I.S.C.I.*, August 31, 1921, p. 598a. (A.W.)

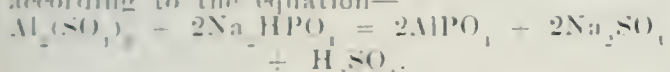
THE ACID AND ALKALINE DECOMPOSITION OF POTASSIUM CYANIDE WITH A NOTE ON THE DETERMINATION OF FORMIC ACID IN THE PRESENCE OF HYDROCYANIC ACID.—In summarising the author states: "It has been shown that only a small proportion of hydrocyanic acid is evolved as gas when potassium cyanide is acted upon by sulphuric acid at ordinary pressure and temperature. This has an important bearing upon the use of gas for fumigation purposes. Except where liquid hydrocyanic acid

is prepared great loss of cyanide is taking place. The means for avoiding their loss are indicated.

"The acid and alkaline hydrolysis of hydrocyanic acid has been stated. The reaction proceeds slowly in both cases, and in acid solutions the hydrolysis to ammonia and formic acid is very incomplete. A simple method is described for determining formic acid in presence of hydrocyanic acid."—GEORGE HARKER, *Journal of Society of Chemical Industry*, August 31, 1921, p. 182. (F.W.)

THE VOLUMETRIC ESTIMATION OF ALUMINIUM.—The method resembles in principle the process for the estimation of chlorides in aqueous solution, which latter method depends upon the difference in chemical affinity between silver nitrate and the chloride on the one hand and between silver nitrate and potassium chromate on the other hand.

Aluminium may be determined similarly by its reaction with secondary sodium phosphate according to the equation—



Silver nitrate is used as an indicator, and gives a yellow precipitate of silver phosphate with the free sodium phosphate at the completion of the above reaction.

Details of the method are as follows:—

Precipitates of iron and aluminium are redissolved and the iron separated by heating with either caustic soda or caustic potash. Iron is removed by filtration, the filtrate is made weakly acid with dilute sulphuric acid and aluminium hydroxide precipitated by ammonia.

The aluminium hydroxide, after washing, is transferred to a porcelain dish and dissolved in dilute sulphuric acid.

The neutral or faintly acid solution is heated to boiling point, and the aluminium precipitated as phosphate with a standard solution of disodium-hydrogen phosphate.

Towards the end of the titration a few drops of concentrated silver nitrate solution are added, and the end of the reaction noted when the solution and precipitate assume a bright yellow colour.

The process is particularly applicable when very small aluminium precipitates are met with, such as mine waters or substances with a low aluminium content.—E. J. KIRBY, *The Chemical Trade Journal*, from *Chemiker Zeitung*, December 21, 1921, p. 7-4. (R.A.C.)

SODIUM CYANIDE.—Sodium cyanide is obtained from mixtures or solutions containing it together with sodium chloride and alkaline earth compounds such as the product obtained by fusing calcium cyanamide with sodium chloride, by precipitating the alkaline earth by adding a suitable sodium salt, such as sodium sulphate or carbonate, and concentrating the solution at the same time, or subsequently so as to salt out the sodium chloride and leave the cyanide in solution. For this purpose sodium cyanide or its mixture with sodium chloride may be added to the solution. If an excess of cyanide is used the part remaining undissolved may be recovered by leaching the remaining solids. (Br. Pat. 164,719, not

yet accepted. Deutsche Gold und Silber-Scheide Anstalt, vorm. Rössler, Frankfurt-on-Main, Aug. 4, 1921.)—(*Chem. and Met. Eng.*, October 26, 1921, p. 802. (J.A.W.)

ALCOHOLIC FERMENTATION AS A SOURCE OF GLYCERINE.—In 1780 Scheele obtained glycerine by the saponification of fats with lead oxide. In 1823 Chevreul proved that glycerine is an integral part of fats in the form of an ester of the fatty acids. This has been confirmed by Pelouze and since then glycerine has been prepared commercially by saponification of fats in soap plants. During the war, due to the scarcity of fats, researches were started to prepare glycerine synthetically or by fermentation. As early as 1873 Friedel and Silva succeeded in preparing glycerine synthetically, but up to now the process has not been an industrial success. The fermentation method at first used by Pasteur has been more successful, and Dr. K. Schweizer gives in the August, 1921, issue of *Chimie et Industrie* a lengthy description of the industrial preparation of glycerine by alcoholic fermentation.

After reviewing the work of Pasteur, Laborde, Ehrlich, Rossi, Neuberg and Kerb, he outlines the facts and hypotheses concerning the intermediate products formed during alcoholic fermentation which are necessary for the manufacture of glycerine as the main product. Among the methods used for the realisation of these changes he gives the following:—

Reduction of Trioses.—Since it is known that glycerine can be obtained by the reduction of glyceric aldehyde and dioxycetone and since these substances are supposed to be formed as intermediate products during the conversion of sugar into alcohol, it seemed logical to expect that the addition of a reducing agent during fermentation would increase the yield of glycerine. The greatest practical difficulty was to find a yeast which would function in the presence of the large quantities of salts constituting the reducing agent. However, by the use of a yeast prepared from molasses, and a great excess of sodium sulphite, it was possible to obtain 21.3 g. glycerine from 100 g. sugar.

Change of the Reaction of the Fermentation Medium.—This is best realised by introducing given quantities of sodium carbonate in the fermentation medium shortly after fermentation started. Twenty to 25 kg. of glycerine can thus be obtained per 100 kg. of sugar.

Blocking the Formation of Acetaldehyde during Fermentation.—This is best realised by using sodium sulphite, which acts not only as an alkaline reagent but also as an antiseptic for the harmful bacteria resulting from the fermentation in alkaline medium. About 23 kg. of glycerine is obtained per 100 kg. of sugar.

The author then describes the method used for the extraction and purification of the formed glycerine. He concludes by suggesting that instead of starting with sugars, which are expensive, there will soon be a possibility of preparing glycerine by using hydrolyzed saw-dust and waste sulphite liquor from paper mills.—K. Schweizer, *Chem. and Met. Eng.*, November 9, 1921, p. 891. (J.A.W.)

THE CLAUDE AMMONIA PROCESS.—Mr. West is associated with the Cumberland Coal, Power, and Chemical Co., which is erecting works at

Workington to operate the Claude Process

With a view of obtaining a supply of hydrogen immediately, and under the best conditions, the Cumberland Company has acquired a controlling interest in the Tissa Water Power Co. in Norway, which has a plant of a capacity of 145,000 electrical horse-power.

The cost of power for the production of hydrogen is about £1 per horse power year, or 1.25th penny per kilowatt hour.

This electrolytic hydrogen plant has a daily capacity of over nine million cubic feet.

The Claude synthetic ammonia process has this in common with the Haber process, it consists in effecting the direct combination of hydrogen with nitrogen under pressure and in the presence of a catalyst to form ammonia. The predominant difference between the two processes lies in the much higher pressure used by Claude, which entirely modifies the working conditions of the process.

Claude's experimental work showed very clearly that for a given temperature the proportion of nitrogen and hydrogen remaining combined under conditions of equilibrium increases rapidly with rise of pressure, and that the lower the temperature the higher is the proportion of combination. The lower the temperature the longer it takes to reach equilibrium, and in order to have apparatus of a reasonable size the reaction must not be too slow.

Claude finds the useful range of temperature to lie between 500° C. and 700° C., and considers it best to work at 600° C. and a pressure of 900 atmospheres as against 200 atmospheres used by Haber.

The hydrogen and nitrogen mixed in proper proportions are first compressed to 100 atmospheres in an ordinary three or four stage compressor, passed through separating bottles to remove condensed water, and oil from the compressor, to the super compressor capable of dealing with enough gas to make 5 tons of liquid ammonia per 24 hours, or 426 cub. ft. per min.

Under Claude's conditions the catalyst vessels are quite small, weighing only 11½ tons against those of Haber weighing 74½ tons for a daily capacity of 20 tons of ammonia. The catalyst tubes are made of a special chromium alloy, cast solid and bored out. The basis of the catalyst is peroxide of iron, made by burning iron in oxygen, and is mixed with other cheap materials to increase its activity.

Under the great pressure the ammonia is liquified by passing through a coil immersed in cold water.

It is computed that a ton of ammonia would cost in power £6 16s. 3d., using coke over gas and steam power at ½d. per unit, and only £2 11s. 11d. in the case of electrolytic hydrogen using hydroelectric power at 1.25d. per unit.—Mr. J. H. WEST, *The Chemical Trade Journal and Chemical Engineer*. Read at a joint meeting of Chem. Eng. Group of the Soc. of Chem. Industry and the Inst. of Mechanical Engineers. November 26, 1921, p. 658 (H.D.B.)

NEW PROCEDURE FOR THE ESTIMATION OF ARSENIC.—A new method for the estimation of small quantities of arsenic is based on the intensifying and fixing action of potassium iodide on the yellow stain produced by hydro-

gen arsenide on mercuric chloride paper. The similar stains produced by the hydrides of antimony, sulphur, and phosphorus are not altered by potassium iodide in this way.

At the conclusion of a test the mercuric chloride test paper is treated with 10% potassium iodide solution, which, acting specifically on the arsenic stain, turns it brown, and at the same time renders it permanent to light and moisture. The arsenic is estimated by comparison of the stain with those produced by known quantities under similar conditions. From 0.0001 to 0.1 mg. can be estimated by this procedure.—J. CRIBIER, *Journal of the Chemical Society*, reprinted from *J. Pharm. Chim.*, 1921 [vii], 24, 241-246, November, 1921, ii 653. (R.A.C.)

DETERMINATION OF AVAILABLE LIME IN QUICK-LIME AND HYDRATED LIME.—For most chemical purposes free or uncombined calcium oxide is the valuable constituent of lime, and in practice limes are bought and sold on this basis. Notwithstanding this fact, there is no generally accepted method for obtaining this value, and there has been for some time a demand from various industries for a practical and reliable method.

At the request of the Interdepartmental Conference on Chemical Lime, a series of comparative analyses was made by the Geological Survey, the Bureau of Chemistry and the Bureau of Standards, each using duplicate samples of high-calcium and high-magnesium quick and hydrated limes representing the four types of lime in use. Complete gravimetric analyses were first made for comparison purposes, and calcium oxide determinations were then made by the seven methods for the determination of free lime given in detail by R. K. Meade in *Concrete*, vol. 10 (1917), Cement Mill Section, p. 25.

The results obtained by the Scaife method were most promising and further investigation of this method at the Bureau of Standards led to the following modified procedure:—

Place 1.4 g. of the carefully prepared and finely ground (passing 100 mesh) lime in a 400-c.c. beaker, add 200 c.c. of hot water, cover, heat carefully and then boil for three minutes.

Cool, wash down cover, add two drops of phenolphthalein and titrate with N hydrochloric acid, adding the acid dropwise as rapidly as possible and stirring vigorously to avoid local excess of acid. When the pink colour disappears in streaks, retard the rate of addition of acid somewhat, but continue until the pink colour disappears entirely and does not reappear for 1 or 2 seconds. Note the reading and ignore the return of colour.

Repeat the experiment, substituting for the 400-c.c. beaker a 1-liter graduated flask carrying a one-hole stopper fitted with a short glass tube drawn out to a point. Cool and add dropwise and with vigorous stirring 5 c.c. less acid than before. Call the number of c.c. used A. Grind up any small lumps with a glass rod flattened at one end, dilute to the mark with freshly boiled distilled water, close the flask with a solid stopper, mix thoroughly for 4 or 5 minutes and let settle for half an hour.

Pipette a 200-c.c. portion, add phenolphthalein, and titrate slowly with 0.5 N hydrochloric acid until the solution remains colourless on standing 1 minute. Call this additional number of c.c. *B*. Then the percentage of available $\text{CaO} = 24 \div 5B$.

Table I presents determinations which were made by the modified method.

TABLE I. DETERMINATIONS OF AVAILABLE LIME BY MODIFIED SCAIFE METHOD.

Sample.	Uncombined CaO Present (Calculated from Complete Analysis.)	Available Lime Found.	
		Operator A	Operator B
Calcium quicklime	93.4	93.4	93.4
		93.5	93.3
Calcium hydrate	87.3	85.0	85.0
		85.0	84.3
High-magnesium quicklime ...	58.0	57.9	58.0
		58.0	58.1
High-magnesium hydrate ...	50.0	50.3	50.0
		50.0	50.1
MgO and CaO (0.7 g. each) ...	19.0	49.3	—
		48.8	—
CaO (precipitated)		100.0	—

All figures are based on the lime ignited at red heat, as prescribed in A.S.T.M. specifications for hydrated lime¹, and the hydrochloric acid was standardized by means of Bureau of Standards benzoic acid No. 48-a, through a sodium hydroxide solution.

It is apparent that the determinations on duplicate samples by the modified method agree within reasonable limits and closely approximate the calculated values. The modified Scaife method is approved by the Interdepartmental Conference on Chemical Lime, and is now being tested in Government and works laboratories.—ALICE J. WHITSON, *Chem. and Met. Eng.*, Oct. 19, 1921, p. 740 (J.A.W.)

STAINLESS IRON.—According to the *Ironmonger* (London), a new stainless iron has been put on the market by three British firms in bars and sheets. It is derived from the well-known stainless steel, and differs from the latter principally in that it contains carbon less than 0.10 per cent. Carbon-free chromium or ferrochromium is thus required, either of which are expensive substances. Therefore the new metal is more expensive than brass, but it is easier to keep clean. This new low carbon chromium-iron alloy is distinctly softer than stainless steel and is thus suited to various manipulations: a wide range of uses in forging, pressing and stamping. Already success is reported in producing automobile wheel discs, brake bodies, and other products subject to corrosion or tarnishing, thus eliminating painting and varnishing.—*Asos. Chem. and Met. Engineering*, October 12, 1921, p. 717 (J.A.W.)

FUEL RESEARCH BOARD'S VIEWS ON LOW-TEMPERATURE CARBONISATION.—In view of low-temperature carbonisation, the Director of Fuel Research (Sir George Beilby) has deemed it desirable to set out the following most recent

views of independent experts who have made a careful study of this subject.

The primary products of the carbonisation of coal at 550 deg. to 600 deg. C. are rich hydro-carbon gas, motor spirit, fuel oils, and coke containing about 10 per cent. of volatile matter, which burns in an open fire with a perfectly smokeless flame. The researches at H.M. Fuel Research Station during the past two years have placed in our hands for the first time trustworthy and independent data as to the yields and qualities of these products as obtained from various types of coal, and under varied conditions of treatment. The design of a form of apparatus by which carbonisation of coal at 550 deg. to 600 deg. C. can be carried out with economy and efficiency is being studied on a practical scale at the Station.

The Fuel Research Board have from the outset recognised that a problem of this kind may at any moment be solved in some unexpected way by an outside inventor. They have therefore kept in touch with all proposals which appeared to contain any germs of possible success. At present there are at least six such proposals, the development of which the Board are watching with close and sympathetic interest. The engineering and technical problems which must be solved before it can be said with confidence that a really practical apparatus has been evolved are of a very difficult character, some of them requiring for their solution knowledge and experience which is only in the possession of a few experts. After each successive apparatus has been erected and subjected to a series of preliminary tests, the final and more exacting test remains of continuous running for a sufficiently long period. This is imperative, because all apparatus which has to be worked at a relatively high temperature tends to deteriorate more and more rapidly with the efflux of time.

In the present unstable condition of industry generally, and of coal and oil production in particular, it is almost impossible to estimate the wider possibilities of low-temperature carbonisation from a national point of view as it would apply to the tens of millions of tons of coal which are at present consumed in the raw state. The Fuel Research Board would hesitate to put forward any economic estimates, their position being that so much still remains to be done on the technical and engineering sides that the only wise course is to concentrate all the available skill and energy on this side of the subject till the present experimental stage has been successfully passed.

In the view of the Fuel Research Board it cannot be too widely understood by the public that, in their opinion, this stage has not yet been reached by any of the proposals referred to, or at H.M. Fuel Research Station—FUEL RESEARCH BOARD, SIR G. BEILBY, *J. and C. Trades Review*, December 10, 1921, p. 866. (J.A.W.)

THE DETECTION OF CARBON MONOXIDE.—An absorbent, Hoolamite, is prepared by mixing together fuming sulphuric acid 53-56%, iodine pentoxide 10.6-12%, and pumice stone 33-35%. At ordinary temperatures carbon monoxide is oxidised by this reagent to carbon dioxide with liberation of iodine, which reacts with excess of sulphur

¹ *Proc. A.S.T.M.*, 1920, p. 629.

trioxide present to form a green substance indicative of the presence of carbon monoxide, and varying in depth with concentration of the gas. On keeping or gentle warming the green colour changes to orange-yellow, and disappears in a few minutes, so that the material can again be used as before until about twelve tests have been made, when the colour produced becomes irregular and a fresh supply of reagent is required. The colour produced in each case is compared with permanent colour standards prepared from a mixture of pumic granules with normal and basic copper acetate and chromium oxide. By this means a quantitative test can be made with gas mixtures containing up to 0.2% of carbon monoxide. Interfering gases such as unsaturated hydrocarbons, hydrogen sulphide, etc., are first removed by passing through dry active charcoal. 0.005% of CO can be detected by passing 500 c.c. of a gas mixture through a glass tube containing a column of Hoolamite 50 mm. X 5 mm. A pocket size detector apparatus has been devised.—C. R. HOOVER, *Journ. of the Chemical Society*, reprinted from *J. Ind. Eng. Chem.*, 1921, 13, 770-772, November, 1921, ii. 654. (R.A.C.)

LEAD POISONING.—A series of lectures on hygiene in relation to industry before the Royal Institute of Public Health was concluded by a lecture on Lead Poisoning by Sir Kenneth Goadby.

Reference is made to a memorandum recently issued by Dr. Legge, the Chief Medical Inspector of Factories, in which it is stated that the attack rate of white lead manufacturers for 1914 was 26 per thousand.

In industries where a considerable amount of risk of lead absorption was present the number of reported cases was always high, a large number of them, however, being of a trivial character, and after a week or two the disease cleared up without leaving any obvious disability. In those industries where absorption was limited in daily amount, but continued over long periods, the incidence of severe cases was always high and had an increased rate of paralysis.

Painters and lead workers show a high incidence of chronic kidney disease, and the former appear to suffer a high mortality through gout, probably due to inhalation of turpentine oil vapours.

The classical symptoms of lead poisoning are: Colic, constipation, a blue line upon the gums, and finally symptoms of palsy, usually manifesting themselves as "dropped wrists," the latter being the chief and unmistakable clinical symptoms by which severe lead poisoning can be recognised.

Any factory air which showed that men exposed to it would inhale more than two milligrams of lead per day must be considered as dangerous, as this is the maximum amount the human body can be expected to resist; some persons are more susceptible than others.

It is particularly important that all cases should be treated at the early stages, so that complete recovery may be effected.—Sir KENNETH GOADBY, *Chemical Trade Journal and Chem. Eng.*, December, 17, 1921, p. 756. (H.D.B.)

POWER ALCOHOL.—The Fuel Research Board (Department of Scientific and Industrial Research) have published their Second Memorandum on "Fuel for Motor Transport." The Inter-Departmental Committee on Alcohol for Power and Traction Purposes, in their Report dated June 23, 1919, recommended that an organisation should be established by the Government to initiate and supervise experimental and practical development work, at home and overseas, on the production and utilisation of power alcohol, and to report from time to time for public information on all scientific, technical, and economic problems connected therewith. The Report was referred to the Committee of the Privy Council for Scientific and Industrial Research, and on the recommendation of their Advisory Council they decided, in the first instance, to appoint a suitable officer with the necessary assistance, under the Fuel Research Board, who would be charged with the duty of collecting accurate data from different parts of the Empire as to the possibility of producing alcohol in bulk from local vegetable materials, and of arranging for the continuance of any experiments and negotiations connected with utilisation which could usefully be undertaken. Accordingly Sir Frederic Nathan was appointed Power Alcohol Investigation Officer under the Fuel Research Board in December, 1919. An Interim Memorandum on Fuel for Motor Transport was issued by the Board in July, 1920. The present Memorandum gives a brief general survey of the work of the Board in regard to Power Alcohol since that date.

The subjects dealt with in the Memorandum include among others (1) production of alcohol in the British Dominions and Colonies; (2) synthetic production from calcium carbide and from the ethylene in coal gas from gasworks and cokeries. Considerable attention has been given during the last two years to the possibility of removing ethylene from coal gas and its subsequent conversion into power alcohol. A manufacturing-scale process has not yet been developed, however, and even should a successful one be worked out, it would still be a question whether it would be profitable to produce alcohol by such process at the expense of the calorific value of the coal gas. Some of the general conclusions arrived at in the Report are:—

(1) The prospect is remote of adding materially to the supplies of liquid fuel for internal combustion engines in this country by the manufacture of alcohol from home-grown materials

(2) The production of alcohol within the Empire from materials containing sugar or starch is only likely to be possible commercially in the near future in some of the Dominions and Colonies, and then only on a sufficient scale to meet local requirements.

(3) It is unlikely that alcohol could be produced in excess of local needs and at a price, when freight to seaboard and to this country is included, at which it would find a market here.

(4) Synthetic production on a commercial scale in this country is unlikely; it might be possible, however, in Canada and Australia.—*Iron and Coal Trades Review*, December 23, 1921, p. 917. (J.A.W.)

A CONVENIENT HUMIDITY TABLE FOR THE WET AND DRY BULB THERMOMETER.—Users of wet and dry bulb thermometers will find the following table, compiled at the Forest Products Laboratory, Madison, Wis., very useful for quickly determining relative humidity values from wet and dry bulb thermometer readings. To use the table, read the temperatures and subtract the wet bulb readings from the dry. Locate the vertical column of figures headed by the appropriate difference between wet and dry bulb readings, and the horizontal row of

figures beginning at the extreme left with the observed dry bulb reading. The figure marking the intersection of these rows is the relative humidity value expressed in per cent.

Take the following as an example: wet bulb temperature, 132 deg. F.; dry bulb temperature, 140 deg.; difference, 8 deg. The figure marking the intersection of the vertical column for 8 deg. difference with the horizontal row beginning with 140 at the extreme left is 79, which is the correct relative humidity for the given thermometer readings.

RELATIVE HUMIDITY TABLE.
Difference Between Wet and Dry Bulb Thermometers—in Degrees Fahrenheit

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	
60	94	89	83	78	73	68	63	58	53	48	44	39	34	30																											
70	95	90	85	81	76	72	68	64	59	56	51	47	43	40	37	33	29																								
80	95	91	87	83	79	75	71	68	64	61	57	54	50	47	44	41	38	35	32	29																					
90	96	92	88	85	81	77	74	71	67	65	61	58	55	52	49	47	44	41	39	36	34	31	29	26	25																
100	96	93	89	86	83	79	76	73	70	68	64	62	59	57	54	51	48	46	44	42	39	37	35	33	31	29	27														
102	96	93	89	86	83	80	77	74	71	69	65	62	59	57	54	52	49	47	45	43	40	38	36	34	32	30	28														
104	96	93	90	87	83	80	77	74	71	69	65	63	60	58	55	52	50	48	46	43	41	39	37	35	33	31	29	27													
106	96	93	90	87	83	80	77	74	72	69	66	63	60	58	56	53	51	48	46	44	42	40	38	36	34	32	30	28													
108	96	93	90	87	84	81	78	75	72	70	66	64	61	59	56	54	51	49	47	45	43	41	39	37	35	33	31	29	28												
110	97	94	90	87	84	81	78	75	72	70	67	64	62	60	57	55	52	50	48	46	44	41	39	37	36	34	32	30	28	27											
112	97	94	90	87	84	81	78	75	73	70	67	65	62	60	57	55	53	51	49	47	44	42	40	38	37	35	33	31	29	28											
114	97	94	90	87	84	81	78	75	73	71	68	65	63	61	58	56	53	51	49	47	45	43	41	39	37	35	34	32	30	28	27										
116	97	94	90	88	84	82	79	76	74	71	68	66	63	61	59	56	54	52	50	48	46	44	42	40	38	36	34	33	31	29	25										
118	97	94	91	88	85	82	79	76	74	71	68	66	64	62	60	57	55	53	51	49	46	44	42	41	39	37	35	34	32	30	29	27									
120	97	94	91	88	85	82	79	77	74	72	69	66	64	62	60	57	55	53	51	49	47	45	43	41	40	38	36	34	33	31	30	28	27								
122	97	94	91	88	85	82	79	77	75	72	69	67	65	63	60	58	56	54	52	50	48	46	44	42	40	38	37	35	33	32	30	29	27								
124	97	94	91	88	85	83	80	77	75	72	70	67	65	63	61	58	56	54	52	51	48	46	44	43	41	39	37	36	34	33	31	29	28	27							
126	97	94	91	88	86	83	80	78	75	73	70	68	65	64	61	59	57	55	53	51	49	47	45	43	42	40	38	37	35	33	32	30	29	28							
128	97	94	91	89	86	83	80	78	76	73	71	68	66	64	61	59	57	55	53	52	49	47	46	44	42	40	38	37	36	34	33	31	30	28	27						
130	97	94	91	89	86	83	80	78	76	73	71	68	66	64	62	60	58	56	54	52	50	48	46	44	43	41	40	38	36	35	33	32	30	29	28						
132	97	94	92	89	86	83	81	78	76	74	71	69	67	65	62	60	58	56	54	53	50	49	47	45	43	42	40	39	37	35	34	32	31	30	29	27					
134	97	94	92	89	86	84	81	79	76	74	71	69	67	65	63	61	59	57	55	53	51	49	47	46	44	42	41	39	38	36	35	34	32	31	30	29	28				
136	97	94	92	89	86	84	81	79	77	74	72	69	67	65	63	61	59	57	55	53	51	50	48	46	45	43	41	40	38	37	35	34	32	31	30	28	27				
138	97	94	92	89	87	84	81	79	77	74	72	70	68	66	63	62	60	58	56	54	52	50	48	47	45	43	42	40	39	37	36	35	33	32	31	29	28	27			
140	97	94	92	89	87	84	81	79	77	75	72	70	68	66	63	62	60	58	56	54	52	51	49	47	46	44	42	41	39	38	36	35	34	32	31	30	28	27			
142	97	94	92	89	87	84	82	80	77	75	73	70	68	66	64	62	60	58	57	55	53	51	49	48	46	44	43	42	40	39	37	36	34	33	32	30	29	28	27		
144	97	95	92	89	87	84	82	80	78	75	73	71	69	67	65	63	61	59	57	55	53	52	50	48	47	45	44	42	41	39	38	36	35	34	32	31	30	29	27		
146	97	95	92	89	87	85	82	80	78	75	73	71	69	67	65	63	61	59	57	56	54	52	50	49	47	45	44	42	41	40	38	37	36	35	33	32	30	29	28	27	
148	97	95	92	89	87	85	82	80	78	76	73	71	69	67	65	63	61	60	58	56	54	53	51	49	48	46	45	43	42	40	39	38	36	35	34	32	31	30	28	28	
150	97	95	92	90	87	85	82	80	78	76	74	72	70	68	66	64	62	60	58	57	55	53	52	50	48	47	46	45	43	42	41	39	38	37	36	34	33	31	30	29	
152	98	95	93	90	88	85	83	81	79	76	74	72	70	68	66	64	62	60	59	57	55	53	51	49	48	47	46	44	42	41	40	39	37	36	35	33	32	31	30	29	
154	98	95	93	90	88	85	83	81	79	77	74	72	70	68	66	65	63	61	59	57	56	54	52	50	49	47	46	44	43	42	41	40	39	38	37	35	34	33	32	30	29
156	98	95	93	90	88	86	83	81	79	77	74	72	71	69	67	65	63	61	60	58	56	54	53	51	49	48	46	45	44	42	41	40	39	37	36	34	33	32	31	30	
158	98	95	93	90	88	86	84	81	79	77	75	73	71	69	67	65	63	61	60	58	56	55	53	51	50	48	47	45	44	43	41	40	39	38	36	35	34	33	31	30	
160	98	95	93	90	88	86	84	81	79	77	75	73	71	69	67	65	64	62	60	58	57	55	53	51	50	49	47	46	44	43	42	41	40	39	38	37	35	34	32	31	
162	98	95	93	90	88	86	84	82	80	77	75	73	71	69	68	66	64	62	60	59	57	56	54	52	51	49	47	46	45	44	42	41	40	39	37	36	35	34	32	31	
164	98	95	93	91	88	86	84	82	80	78	75	73	72	70	68	66	64	62	61	59	58	56	54	52	51	49	48	47	46	44	43	41	40	39	38	36	35	34	33	32	
166	98	95	93	91	88	86	84	82	80	78	76	74	72	70	68	66	65	63	61	59	58	56	54	53	51	50	48	47	46	44	43	42	41	39	38	37	36	35	34		
168	98	95	93	91	88	86	84	82	80	78	76	74	72	70	68	67	65	63	61	60	58	56	55	53	52	50	49	47	46	45	43	42	41	40	39	37	36	35	34	33	
170	98	95	93	91	89	86	84	82	80	78	76	74	72	70	68	67	65	63	62	60	59	58	56	54	53	52	51	49	48	47	45	44	43	41	40	39	38	37	35	34	
172	98	95	93	91	89	87	84	82	80	78	76	74	73	71	69	67	66	64	62	61	59	58	56	54	53	51	50	48	47	46	44	43	42	41	39	38	37	36	35		
174	98	95	93	91	89	87	85	83	81	78	76	75	73	71	69	67	66	64	62	61	59	57	56	54	53	51	50	49	47	46	45	43	42	41	40	39	37	36	35		
176	98	96	94	91	89	87	85	83	81	79	77	75	73	71	70	68	66	64	63	61	60	58	56	55	53	52	50	49	48	46	45	44	43	42	40	39	38	37	36		
178	98	96	94	91	89	87	85	83	81	79	77	75	73	72	70	68	66	64	63	61	60	58	56	55	54	52	51	49	48	47	46	44	43	42	41	39	38	37	36</		

Chem. and Met. Eng., October 19, 1921, p. 746 (J. A. W.)

METALLURGY

COMMERCIAL ELECTROLYTIC IRON.—During the war some interesting work was done in France and England on building up worn or defective machine parts by electro-deposition of iron. (See Mr. B. H. Thomas's Paper on 'Electro-Deposition of Iron in Repair Work' in our issue for May 14, 1920.) It remained for the Société 'Le Fer' in France to devise a process for producing electrolytic iron commercially. For six years Les Fonderies et Forges de Sainte-Maurice et Grignon and the works of Messrs.

Bouchayer & Vinlet at Grenoble have manufactured pure-iron boiler tubes in competition with established practice. The French process originated in the researches of Anthéline Bouchayer in 1919 and was not put into operation until several years of experimentation had passed.

In brief, the process consists of electrolyzing a concentrated solution of ferrous chloride at a temperature of 70°C . The anodes are of cast iron, the cathode is a rotating mandrel of steel. The current density employed is 1,000 amp. per sq. m., and the use of depolarizers

permits the deposition of dense smooth iron of any desired thickness. It is a great advantage of this process that tubes and sheets of any desired gauge can be made, since the thickness of deposit may be controlled absolutely. At the Bouchayer establishment in Genoble, tubes are made 4 to 5 m. long, 10 to 20 cm. in diameter, and from 0.1 to 6 mm. in thickness. These works are selling a tube made to a certain gauge without drawing. The irregularities of wall thickness so common to the present commercial tube are avoided in the electrolytic tube.

This process, like those of Burgess, Cowper-Coles, and Fischer, requires the use of soluble anodes with the inevitable losses in slimes. It was with the idea of utilising iron ores directly (without the use of the blast furnace) that Mr. F. A. Eustis, of Boston, and Mr. C. P. Perin, of New York, developed what is known as the Eustis process. This differs from preceding methods in that an insoluble anode is used. The iron is deposited on a rotating cathode, but a diaphragm separates the anode and cathode compartments. At the anode an oxidation of ferrous chloride takes place, and by keeping a hydrostatic head on the catholyte, diffusion is reduced to a minimum. The process is described by Messrs. C. P. Perin and Donald Belcher, of Perin and Marshall, consulting engineers, New York, N.Y., in a recent issue of *Mining and Metallurgy*.

The researches on this process were carried on at the Massachusetts Institute of Technology by Prof. C. R. Hayward, in conjunction with Messrs. H. M. Schleicher and Donald Belcher. The ores used have been mostly sulphide. The ferric chloride formed at the anode compartment of the cell is led over the sulphide ore, thus reducing the ferric chloride and effecting the solution of iron at the same time. Sulphur, deposited in the gangue, is recovered as brimstone. Any copper that is dissolved must be removed by precipitation on scrap iron, and offers another by-product. The pyrrhotite ore, on which the stress was laid in this research, is the cheapest and one of the most abundant ores in North America. How this process, unique in iron metallurgy, converts this ore into valuable products is shown by the fact that, with ease, 90 per cent. of the iron must be recovered as pure electrolytic iron, and 90 to 95 per cent. of the sulphur as brimstone. The current density may be varied over a wide range, 20 to 100 amp. per sq. ft.; the voltage varies from 1.5 to 4.0 volts. The use of chemical depolarisers and addition agents has been avoided.

A number of tubes have been made by this process. The iron of these is most compact, consisting of a fine network of ferric crystals; its resistance to atmospheric corrosion, as compared to wrought iron and low-carbon steel, is marked. Tests made in 5 per cent. sulphuric acid at room temperature showed wrought iron to corrode nearly twenty times as fast as electrolytic iron.

The Eustis process uses no solid fuel, and therefore enters into direct competition with electric smelting operations, but with the advantage that the expenditure of electrical energy per ton is much less. A sample of the iron was submitted to chemical analysis, and gave the following results: Sulphur, 0.002 per

cent.; silicon, 0.002; phosphorus, 0.0016; carbon trace (not over 0.003). This would show the iron to be more than 99.99 per cent. pure; thought to be the purest iron on record.

Pure iron is wanted for making special steel, boiler tubes, electric motors, generators, transformers, telegraph wires, and for many other purposes. It has unusual mechanical and electrical properties which open up many special fields. Moreover, it may be used to replace iron or steel in sheets and tubes on a purely price-competition basis.

From Escard's articles in the "Génie Civil" we learn that a French tube about 4 in. in diameter, and 0.03 in. thick withstood a bursting pressure of 1,110 lbs. per sq. in., which amounted to a fibre stress of 73,500 lbs. per sq. in. The high ductility of the iron is shown by the fact that a tube may be drawn through five reductions without reheating. Particularly striking is an experiment performed on a cone 12 mm. high and 16 mm. in diameter at base, which was flattened out until the base was 40 mm. in diameter without the circumference cracking.

Tests made by the National Tube Company and others show electrolytic iron to have a yield point of 52,000 lbs. per sq. in., and an ultimate strength of 40,000 to 80,000 lbs. per sq. in., depending upon the heat treatment. The scleroscope hardness was 57, dropping to 11 on reheating. The Brinell hardness was 158, dropping to 54. The elongation was 12 per cent. on an 8-in. strip, and the reduction of area 50 per cent.—F. A. EUSTIS, *Iron and Coal Trade Review*, January 6, 1922, p. 11. (J.A.W.).

PLATINUM IN 1921.—Stocks of platinum at the beginning of 1921 were 46,747 oz., nearly 75 per cent. greater than in the previous year. Imports for the first nine months of 1921 were 52,200 oz., or slightly lower than in 1920. However, the available platinum was apparently more than sufficient for the decreased demands, particularly of the jewellery industry, as the price for the metal continued to decrease until

July, when the low level of 65 dollars per ounce was reached. After midsummer there was an increase in price, and by mid-November 85 dollars was asked for small quantities of platinum. More recently the market has eased, and it appears probable that platinum may decline further.

Average Monthly Prices of Platinum.
Dollars per Troy Ounce in New York Market.

Months	1917	1918	1919	1920	1921
Jan.	87.83	105.92	104.85	154.23	73.400
Feb.	103.75	107.68	100.43	151.59	70.227
Mar.	103.33	108 (nom.)	99.20	138.56	72.463
April	103.77	108 (nom.)	99.85	127.04	73.404
May	105.00	106.27	102.60	97.50	73.740
June	104.75	105.00 (a)	105.80	85.19	74.942
July	103.88	105.00 (a)	105.90	83.94	70.440
Aug.	104.55	105.00 (a)	107.60	111.44	73.222
Sept.	104.13	105.00 (a)	128.79	115.20	75.960
Oct.	104.00	105.00 (a)	132.21	101.70	81.800
Nov.	104.52	105.00 (a)	136.74	84.75	82.609
Dec.	104.38	105.54	151.35	79.62	78.192
Year	102.82	105.95	114.61	110.90	75.033

(a) Fixed price.

Columbia still continues to supply over half of the crude platinum demand of the United States, though both England and France have contributed considerable metal. Japan has placed an embargo on the exportation of platinum, apparently with the purpose of building up a reserve, for she has taken over half of the unmanufactured platinum exported from the United States, and has undoubtedly been in other markets as well.

Iridium, which was quoted at 325 dollars per ounce at the first of 1921, gradually lessened in demand, apparently reflecting the slump in the automobile industry. By midyear the price had declined to 160-170 dollars per ounce, and it is reported that towards the close of the year holders of iridium or osmiridium could find no bidders for their metal. It was hoped that Mr. Urquhart's negotiations in Russia might result in renewed mining activity in that country, but the Soviet Government was not ready to listen to reason, so another year has been lost in re-opening the world's richest platinum mines.

The Canadian nickel mines were closed in the fall of 1921, which will result in a loss of several hundred ounces of platinum and palladium a year. The Columbia production should continue to increase, and there is every reason to feel that the domestic market should have sufficient supplies during 1922 to assume a somewhat lower price for all of the platinum group metals. —JAMES M. HILL, Geologist, United States Geological Survey, by permission of the Director, *Engineering and Mining Journal*, New York, January 21, 1922, Annual Progress Number, pp. 86-87. (J.W.).

THE FROTH FLOTATION PROCESS AND METALLURGICAL COKE—The beneficial effect on the physical strength of metallurgical coke made from coking coals after treatment by the Froth Flotation process of cleaning has been further demonstrated by practical trials that have taken place in South Wales under the supervision of Minerals Separation, Limited. The results of one of these tests are set out in Table I.

TABLE I.—*Test of Metallurgical Coke made from Coking Coal Cleaned by the Froth Flotation Process.*

Analysis, &c.	Flotation Ordinary		
	Coal	Coke	Coke
ash (per cent.)	1.70	0.00	—
Sulphur (per cent.)	0.97	1.14	—
Vol. matter (per cent.)	13.45	0.86	—
Moisture (per cent.)	13.45	0.86	—
Sp. gravity	—	1.39	—
Porosity	—	1.40	—
Crushing strength (lbs. per sq. in.)	—	2,076	1,500 & under

Further research has demonstrated that where the coking properties of a coal are neutralized by the presence of fusain, differential flotation may be applied for removal of the latter, leaving a residual fuel strongly coking in character. Success in this direction is shown by the series of semi-commercial tests on Scottish coals given in Table II, which before treat-

ment were very inferior in coking properties (the coking constituent thus separated is denominated *bright* in the table):—

TABLE II.—*Samples of Coke made from Scottish Coals after Treatment by the Froth Flotation Process.*

Material	Analysis					
	Product	Weight per cent.	Moisture per cent.	Ash per cent.	B.T.U.	Vol. matter per cent. Coke
Original	Original	100.0	—	5.74	13,273	34.32
	Bright	80.0	8.0	4.34	13,760	26.12 Good
	Dull	20.0	—	10.36	12,877	25.73
Original	Original	100.0	—	15.82	12,084	22.36
	Bright	70.5	18.0	4.56	13,561	26.52 Very good
	Dull	29.5	—	50.08	—	17.92
Original	Original	100.0	—	8.30	12,877	25.54
	Bright	53.7	6.4	4.90	13,273	23.60 Good
	Dull	46.3	—	11.78	12,680	22.69
Original	Original	100.0	—	8.30	13,075	34.65
	Bright	63.3	—	4.34	13,650	33.37 Very good
	Dull	36.7	—	11.58	12,877	33.21

This section of the research is in its early stages, and it is not yet to be inferred that the Minerals Separation Processes are applicable to all non-coking coals for obtaining a coking product. It may, however, be taken as established that, where the non-coking properties of a coal are due to the presence of fusain, the fusain can be removed, leaving an excellent coking product.

This discovery marks a new stage of development in the preparation of metallurgical fuels. Many iron ores are at present unexploited owing to a dearth of coking coal, and the differential method may well lead to far-reaching economic developments in those countries at the moment industrially impotent in so far as concerns coking coal. —ERNEST BURY, *Iron and Coal Trades Review*, January 6, 1922, p. 2. (J.W.).

MINING.

SCRAPING AND LOADING IN MINES—Operators have, of late, devoted considerable attention to the solution of ore handling problems, particularly in stopes. The inefficiency in shoveling and its attendant high cost has led to the development of a number of shoveling and loading machines and appliances. Such a machine must not be too heavy and its application must provide for flexibility.

The author states that a solution to the problem lies in the use of scrapers drawn by small compressed air hoists. This scraper is similar in design and operation to the familiar horse-drawn scraper seen every day in surface excavating work or to the drag-line scraper used in ditching and large excavation work.

For use underground the small compressed air hoist is usually mounted on a turn-table,

which is made fast to a timber skid or a truck, the whole being placed behind one of the chute raises and blocked down. One man operated the hoist, another the scraper. He carries it to the pile of broken ore, holds it by the handles at the proper angle as it is pulled into the ore by the hoist, and then follows the load as the scraper is pulled to the chute. When it is not possible to have a straight haul the operator steers the scraper around a slight turn, or where this is too abrupt a snatch block is brought into use. Where loading chutes are not accessible trucks are loaded direct, the scraper being pulled up an incline of planks. The scraper in use on the iron mines holds approximately 3 cu. ft. If the ore is fine it will push along up to 5 cu. ft.

The principal advantages claimed are simplicity, low first cost and flexibility, and saving in lashing cost. The disadvantage is the hard manual labour involved. It is in use in coal mines, iron mines, and copper mines, where the workings are rather flat.—WARD ROYCE, *Engineering and Mining Journal of New York*, 10th December, 1921, p. 925. (F.W.)

GEOLOGICAL METHODS OF THE HOMESTAKE GOLD MINING Co.—At the Homestake Gold Mine geological work was formerly considered unnecessary. To-day two geologists are employed, so that prospecting can be carried on in a more intelligent manner. The geological department of this mine is mapping out in detail a surface area of 25 square miles and 22 mine levels, with a total of 66 miles of drives and cross-cuts, besides stopes in various stages of development.

The ore has been found to be associated with the folding, so that the problem of ore finding has resolved itself into one of working out the location and exact structure of the major folds and then the location and structure of the minor or drag folds.

In surface exposure mapping the tracing of certain prominent or key beds has been found the best means of working out structure. In so doing it has been found that their course across country has been a devious one, and by carefully plotting them the structure is generally completed. The quartzites serve as the best key beds and, being more resistant than shales or schists, their outcrops are more prominent. In tracing key beds it is found necessary to keep in mind the alterations that may take place along the strike, such as variation in deposition, change in general appearance due to dynamic metamorphism in the intensely folded areas and metamorphism due to proximity of igneous intrusives.

In underground mapping all formations, contacts, water courses and faults are mapped in detail. Many specimens are taken for assay and petrographic examination. The scale of the cross sections of the mine are 100 feet to lin. Vertical sections are made at 1,000 feet intervals. This gives four vertical divisions of the developed ore body of an average depth of 2,350 feet. Porphyry dykes cutting through the Homestake ore body have in places disconnected and completely enclosed blocks of ore. This has been brought out in the mapping.

Most exploration is carried out by diamond-drilling. The geology of the bore is carefully plotted and correlated. Records of petrographic

and microscopic work show texture of rock; original structure; secondary structure; percentage and kind of primary, secondary and metamorphic constituents; percentage and kind of accessory minerals; nature of ground mass and description of mineralization. Whenever practicable photograph records are made of rock exposures, contacts and folds. These form useful evidence of structure after the rock has been mined or caved.—L. B. WRIGHT and J. O. HOSTED, *Engineering and Mining Journal of N.Y.*, December 3, 1921, page 887. (F.W.)

MASKS AS PROTECTION IN FIRE FIGHTING.—Gases and vapours may cause three atmospheric conditions dangerous to life. Dr. H. Foster Bain, Director of the United States Bureau of Mines has issued a statement regarding these conditions, in which he gives the following information and advice.

First, in warfare, there are poisonous gases from shells or bombs which, as they are discharged usually in the open air, occur in low concentrations; that is, the actual percentage is small and there is no material depletion of oxygen. This condition was met efficiently by the army gas masks.

Second, in industries, high concentrations of such gases as ammonia, sulphur fumes and carbon monoxide may be encountered through accidents or repair work, though usually there is plenty of oxygen in the air for breathing. This condition may be met by the use of masks with special absorbents. Army masks are valueless for carbon monoxide and high concentrations of ammonia and many other gases.

Third, in confined spaces, such as in tanks, basements and in mines, following explosions or fires, there may be poisonous gases, fumes or inert gases in such quantity that the oxygen content may be so reduced that the atmosphere will not sustain life, independent of the toxic effect of the gases. In this condition, no mask is of any value.

Use of army masks and other masks has led to a number of deaths in fire fighting, in cleaning petrol tanks, and in entering mines in which there have been fires. Only self-contained breathing apparatus that supplies abundant oxygen is of avail in these places.

A mask has been developed by the Bureau which will allow the wearer to enter smoke and fumes given off in the open air or in large open buildings, but it must be borne in mind that when there is deficiency of oxygen, as in mines after explosions or fires, in confined spaces, in surface fires, in basements or closed rooms or where illuminating gas or petrol vapour may be present in high concentration, only self-contained breathing apparatus, otherwise termed oxygen breathing apparatus, can be safely used.

Insufficiency of oxygen gives no warning. Rapid changes may occur in the air of a mine after an explosion or during a fire, and a man wearing a gas mask may drop without warning when he encounters an atmosphere deficient in oxygen. The Bureau therefore recommends, on the basis of present evidence, that only self-contained oxygen breathing apparatus should be used in mines following explosions or fires.—DR. H. FOSTER BAIN, *Mining and Metallurgy*, reprinted from Bureau of Mines, U.S.A., February, 1922, p. 69. (F.W.).

THE PRESERVATIVE TREATMENT OF MINE TIMBER.—The author describes the general condition of timber placed underground, its short life and the desirability of prevention of decay.

In general a tree is composed of duramen or heartwood and alburnum or sapwood. It is the latter which is subject to decay, not only because of its position on the outside but because it contains the living cells which are subject to attack by fungi. Fungi are propagated chiefly by spores, which, when ripe, are discharged in clouds, float about in the air, and in settling on wood infect it. The spores penetrate into cracks of the wood, where they germinate and spread. Infection or transference of disease is easily effected by the tools used in working wood or even through the clothes of the miner. Decayed wood left lying about is a ready source of infection of new, clean timber.

Seasoning of the wood is important. The bark should be stripped off and the timber at least air dried. Correct stacking and attention to ventilation are fundamental requirements.

Two problems must be solved in the treatment for preservation. First, an antiseptic chemical must be found which is toxic to fungus growth; second, a method of application of this chemical has to be developed. The following preservatives have been used chiefly:—

Creosote, which is well-known. It is high in cost in many localities, renders mine timber uncomfortable in handling, and is highly inflammable.

Zinc chloride, a water soluble reagent, has been widely used.

Mercuric bichloride, is a powerful antiseptic, but is very expensive.

Sodium chloride, was formerly used in ship-building.

Iron sulphate is considered useful for tanniferous woods, but with others decomposes on oxidation forming sulphuric acid and thus destroying wood cells.

Copper sulphate is suitable underground where waters are rich in iron.

Sodium fluoride has been found effective and used in Austria.

Three methods of treatment are discussed. Brush treatment, open tank treatment and pressure treatment. For Witwatersrand timber the last two need only be considered.

In place of the common zinc chloride the waste liquor zinc sulphate from reduction works was experimented with and has been found to serve as an effective toxin to fungus growth. Practical tests were conducted over several years at the Ross Deep Mine and the Consolidated Main Reef Mine with great success. A mixture of zinc sulphate and sodium chloride was also used, but was not found superior to the simple zinc sulphate.

The advantages to be gained with this reagent besides preservation of timber, are cheapness and the feature of non-inflammability. The saving to be effected on one mine for drive timber only is estimated at £9200 per annum. In the course of the investigation which was conducted on the commonly used waste and gave timber an absorption of one-half pound of zinc sulphate per cubic foot of timber was

aimed at.—L. D. HINGLE, *The Journal of the South African Institution of Engineers*, March, 1922, p. 152. (F.W.)

MISCELLANEOUS.

ANTHRACOAAL.—Anthracoaal is a dense coke formed by distilling a mixture of small anthracite coal and coal-tar pitch or other suitable bitumen (cf. U.S.P. 1,287,382; J., 1919, 128A). It may be made in a coke oven, and when pushed from the oven tends to remain in large masses which are broken under a hammer and show an irregular fracture. Anthracoaal is denser and tougher than coke. The proportion of pitch used in the mixture is 16–17 per cent., varying slightly with the character of the coal and the method of grinding and mixing. The amount of by-products in anthracoaal gas is $\frac{1}{4}$ – $\frac{1}{2}$ of that in gas from bituminous coal, and it is doubtful whether any form of by-product recovery would be commercially feasible.—D. MARBLE, Amer. Inst. Min. Met. Eng., *Journal of Society of Chemical Industry*, October 15, 1921, p. 681A. (A.W.)

IRON BACTERIA IN RELATION TO THE INCRUSTATION OF PIPES.—Illustrations are given of *Leptothrix*, *Gallionella ferruginea*, *Cladathrix dichotoma*, *Crenothrix polyspora*, and *Spirophyllum*, all found in this country. As they are saprophytes particular attention should be paid to the organic matter contained in water passing through pipes; this should be measured by the number of bacteria that the water can support rather than by chemical analysis. Acid waters are more favourable to iron bacteria than alkaline or soft silicious waters; the bacteria can multiply in the absence of iron, but in its presence they promote the oxidation of ferrous compounds. *Gallionella* and *Spirophyllum* are responsible for the slimy streamers found on the walls of reservoirs and pipes. Although the water may contain only 1 pt. of iron in 1,000,000 this will accumulate in the cell walls of the bacteria; the dead organisms furnish organic matter for the next generation. Tubercular incrustations upon iron pipes result from the presence in the water of carbon dioxide, the concentration of which is locally increased by bacteria. Iron incrustations upon non-ferrous surfaces are entirely due to bacteria. When iron bacteria are found in water the organic matter should be removed by aeration, by the growth of green plants, by bacterial action on filters, and by allowing animals to feed upon it at the surface of the water. Iron in the tenuous form combined with organic radicles will be partly removed by these methods.—D. ELLIS, Sect. G, Brit. Ass., 1921, *Engineering Joint Soc. Chem. Ind.*, October 31, 1921, p. 747A. (A.W.)

Power Gas from Sewage.—In an experimental station at Birmingham, gas emanating from sewage sludge from which the liquid has been separated is used for generating power for purposes connected with the purification of the sewage. The installation consists of a 34 h.p. gas engine which drives a sludge pump, two sludge digestion tanks for the generation of gas, and a gas holder; it is designed to give

25 b.h.p. for six hours per day. The engine was designed to work on town gas, but no adjustments were necessary. The sewage gas contains 13.3 per cent. of methane in addition to hydrogen, nitrogen and carbon dioxide. Under the low temperature conditions of this country a reliable supply of gas for power purposes may be obtained from the sewage sludge rather than from the liquid sewage. In the absence of the liquid, hydrogen sulphide is rarely generated.—J. D. WATSON, Sect. G., Brit. Ass., 1921, *Engineering, Jour. Soc. Chem. Ind.*, October 31, 1921, p. 718A. (A.W.)

INDUSTRIAL FILTER CLOTHS.—Filter fabrics can be divided into two main classes—those used for neutral and those used for corrosive liquors. The latter are mainly special media of wool, metal, asbestos, stone, etc. For non-corrosive liquors cotton is generally used.

Cotton filter fabrics are made up in duck or plain twill, or chain weaves. Plain weave has the square or right-angle appearance of all ducking. Twill has the diagonal lines so characteristic of its weave. Chain has a herring-bone appearance. Muslins and drills are trade names for very light duck and twill weaves.

If the cloth is open or so thin as to prevent the finer particles from collecting within the fabric, discharge of the cake from the surface cleans the cloth. Experience has proved, especially in the case of sluicing discharge, that the surface of the cloth must be smooth for the best results. A duck weave has proved a better cloth than a twill for this reason. A new filter cloth held up against the light may show open pores and yet become positively dense when wetted or in operation for a few runs. In this case the reverse current cannot permeate well and tends to belly out the cloth without lifting the cake away from the cloth. The nap or hairy surface of the yarn is of importance. The nap in the yarn exercises an effect similar to that of the hair in wall-plaster. The nap is the loose end of the cotton, and is, of course, greatest in the short staple stock. Egyptian and American long staple make cloths of the best discharging quality. The cheaper grades are sometimes singed to burn the nap.

There are means of protecting a cloth so as to prolong its life, but none is more effective than adequate support in the drainage member. A supporting screen should have a protector for light cloths. An open weave burlap cover or support is often the most satisfactory. This cushions the filter medium against the drainage member and often adds to capacity.

Primal consideration is no longer given to the rate of filtration of the cloths. With few exceptions the resistance of the depositing cake to the flow is many times that of even dense cotton ducking. Most operators are realising that the true filter medium is the layer of solids which is being deposited out of the liquor.

Dealing with corrosive liquors, for weak caustics like milk of lime, cotton can be used. Precautions must be taken, however, to prevent concentration of the caustic. Wool is the least advisable material to use on caustics. For an acid liquor wool is quite suitable. Strictly speaking, the best acid filter medium is silica or other inert compounds, such as carborundum. Filtros, a porous fused silica, is typical

of the class of media. Mechanically, these do not lend themselves so well on account of a tendency for solids to penetrate their surface.

Metallic cloths are used to an extent. For cleaning the fouled filter media, chemical treatment is advised.—A. WRIGHT, *The Chemical Trade Journal and Chem. Engineer*, American Chemical Society, page 621, November 19, 1921. (F.W.)

THE PHOSPHATE INDUSTRY: SOURCES OF SUPPLY OF MINERAL PHOSPHATE.—The author remarks that in pre-war days little interest was taken in mineral phosphate, but a shortage almost amounting to a world famine directed attention to the known deposits. Unfortunately his table of the various producing countries and their outputs only goes as far as 1913.

	1907. Long Tons.	1913. Long Tons.
United States	2,301,000	3,161,000
Tunis	1,069,000	2,284,000
Algeria	315,000	461,000
France	375,000	335,000
Belgium	181,000	219,000
Christmas Island	290,000	152,000
Other Pacific Islands...	190,000	422,000
Other Countries	58,000	195,000
	<hr/> 4,779,000	<hr/> 7,229,000

He gives the average yield of calcium phosphate from beds that are being worked. Important fresh discoveries have been made in Morocco and Algeria. A Palestine discovery in 1916 made by a German is said to have by borings shown a depth of approximately 65ft., and an average value of 72% of calcium phosphate, in places rising to 83%. There appear to be many others of similar character.

He concludes that it is impossible in the space available to deal with every known phosphatic deposit in detail, but all the more important have been referred to in an attempt to show the magnitude of the industry which has arisen from Lawes' first experiments in dissolving coprolites.—W. PACKARD, *Journ. Soc. Chem. Ind.*, August 15. (A.W.)

CHANGES OF ADDRESS.

ANDERSON, R. C., *I/o* Bengoni; New Medderfontein G.M. Co., Ltd., P.O. Van Ryn.

DEGENHARDT, W. R., *I/o* Nanttu, India; 1, London Wall Buildings, London Wall, London, E.C.2.

LEE, W., *I/o* Union, Club, Johannesburg; Reliance Gold Mine, Ivy Post Office, Barberton.

READ, H. A., *I/o* Rand Mines, Ltd.; The Co-operative Exchange Yard, Ltd., P.O. Box 6103, Johannesburg.

REIM, E. P., *I/o* Peitermaritzburg; The Technical College, Durban.

ROBERTSON, L. A., *I/o* Swazi Coal Mines, Swaziland; *c/o* Witbank Colliery, Ltd., Witbank.

THE JOURNAL

OF THE

Chemical, Metallurgical and Mining Society OF SOUTH AFRICA

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Vol. XXII.

APRIL, 1922.

No. 10.

Proceedings

AT

Ordinary General Meeting, 22nd April, 1922.

The Ordinary General Meeting of the Society was held in the Assembly Hall, Scientific and Technical Club, 100, Fox Street, Johannesburg, on Saturday, the 22nd April, 1922, at 8 p.m., Mr. F. Wartenweiler (President) in the Chair. There were also present:—

29 Members: Messrs. C. J. Gray, Prof. G. A. Watermeyer, F. W. Watson, J. R. Thurlow, H. R. Adam, J. Chilton, A. King, J. E. Thomas, John Watson, A. Whitby, H. A. White (Members of Council), W. Beaver, J. Q. Braidwood, Dr. W. A. Caldecott, R. A. Cooper, J. M. Dixon, W. S. Gordon, Jas. Gray, J. Henderson, E. Homersham, A. McA. Johnston, W. C. Lindemann, Lt.-Col. E. Pam, T. Proberts, J. F. Pyles, C. B. Simpson, Prof. G. H. Stanley, W. E. Thorpe, and H. R. S. Wilkes

5 Associates: Messrs. J. A. Boyd, G. J. V. Clarence, C. E. Deakin, J. Gibson, and A. A. Wood

2 Visitors and H. A. G. Jeffreys (Secretary)

MINUTES

The Minutes of the Ordinary General Meeting, held on the 18th February, 1922, as reported in the February *Journal*, were confirmed

The President said in regard to the March meeting, which was to have been held on the 18th of that month, and was first postponed, and then abandoned, that because we were just emerging from the troublesome period which terminated the strike, it was resolved by the Council that it would not be opportune to hold a meeting at that time. He was glad to state that the Members of

the Society had come out of the disturbances with credit to themselves, and as sound citizens, and that no serious casualties were suffered by its Membership. An opportunity presented itself to do something tangible and to establish the public prestige of men engaged in these pursuits, when the Government called upon the Associated Scientific and Technical Societies, to which we belong, to maintain essential services for the City of Johannesburg. By the successful performance of the task a valuable service was rendered to the community. In this connection the Council at the last meeting had passed a resolution touching upon this matter, which was as follows:—"That this Society herewith confirms the action of its representatives and that of the Controlling Executive of the Associated Scientific and Technical Societies of South Africa in setting an example of good citizenship and a high sense of public spirit to the community; that it places on record its high appreciation of the work done by the Special Committee appointed to assume direct responsibility, and congratulates them on the successful performance of their task under exceptional circumstances; also that it desires to place on record its heartfelt thanks to the Police, Military Force, and Volunteers, who came to the help of the Community and the State when its existence was threatened."

Mr. Jas. Gray said he had much pleasure in moving as an unopposed motion that the action of the Council in approving of its representatives' action on the Controlling Executive of the Associated Societies be confirmed, and that the further resolutions bearing on the unfortunate period

through which we passed last month be endorsed.

He wished to say in this connection that we who are residents on the Witwatersrand know full well that our experiences were a horrible reality and not a figment of the imagination as some of our so-called representatives in another place would have us believe.

An especial debt of gratitude went out to those of our scientific and technical brethren who at the nerve centre of the town—the Power Station—maintained those essential services on which the observance of law and order was so largely dependent.

To those who came to the aid of the State in various capacities during this period we were deeply indebted, and to the bereaved our fullest sympathy extended. In a crisis like that through which we had passed it must prove a source of gratification to the Government to know that it possessed citizens who realise the responsibilities and obligations entailed by citizenship.

NEW MEMBERS.

A ballot was taken for the election of new members and the following were declared

unanimously elected:—

COTTELL, G., P.O. Box 14, Springs: Mine Captain.
CRICHTON, Charles, P.O. Box 2, Benoni: Metallurgist and Chemist.

CULLINAN, Thomas W., P.O. Box 286, Johannesburg: Director of Companies.

FRANCIS, Ernest, P.O. Box 1643, Cape Town: Boring Engineer.

HENNESSY, E. C. C., P.O. Box 2536, Johannesburg: Ex-Mine Secretary.

HURTZIG, George H., P.O. Box 2, Benoni: Mining Engineer.

PHILLIPS, Frank N., P.O. Box 1169, Johannesburg: Director and Chairman of Companies.

TURNBULL, J., P.O. Box 14, Springs: Shift Boss.

The Secretary announced that the following gentleman had been admitted as an Associate:—

WILKINS, Arnold K., P.O. Box 314, Johannesburg: Insurance Manager.

OBITUARY.

The President, regretted to have to announce the death of one of their Members since the last meeting, namely, Mr. Henry William Pridgeon, Manager of the West Springs Gold Mine. He called upon members present to pass a vote of condolence and to rise from their seats out of respect. (The vote was passed in silence, all members rising.)

Mr. J. Henderson then delivered the following lecture:—

THE DEVELOPMENT OF THE BLAST FURNACE.

By J. HENDERSON.

Mr. President and Gentlemen, it is with a certain amount of diffidence that I bring before a Society like this the subject of iron and steel metallurgy. But if any excuse is needed at all it is in the first place that such an industry is about to be started in this country, and secondly it is an industry of extreme importance. I think we must all admit that the primary industry in this country is agriculture. It is perhaps the most important industry to humanity, and then I claim that the iron industry comes next. Of course you gentlemen as representing the gold industry may feel inclined to dispute this contention, but when you think of the enormous value that the iron industry is to humanity I think you will agree that it is entitled to second place both in peace and in war. We shall all agree that if it had not been for the enormous iron and steel resources of the Allies we should never have defeated the Central Empires, and it is therefore the duty of every country that has iron resources to try

to develop them as much as it can, in the first place for peace purposes, and after that for defensive purposes. The importance of iron workers with regard to national defence is illustrated very closely in an instance which happened in the days of the Israelites. When the Philistines conquered them we are told that they took away the smiths into captivity, because they knew that while they held the iron workers prisoners the people were practically defenceless. The same thing holds good at the present day.

We have no record as to when or how or where iron was first discovered. Its discovery was probably accidental, as, for instance, through a piece of rich iron ore becoming embedded in the charcoal burner's pile. We do know that for centuries iron was smelted in rude hearths with charcoal, urged with goatskin bellows. On an Egyptian tomb there is a representation of a furnace of this description showing a couple of men working goatskin bellows with a fire in between. When Captain Speke was

exploring in Africa in the middle of the last century he came across black men making iron, and Colonel Grant, who was with him, made a sketch of the furnace, which is practically identical with that described on the old Egyptian tomb. He gave this sketch to the late Sir Lethian Bell: I have seen it and the only difference between the two is that in the Egyptian drawing the men are working the bellows with their feet and in the other sketch the bellows are worked by hand. These two men would practically make about 12 lbs. of wrought iron in a day. It is rather interesting to relate that these explorers presented the natives with some British wrought iron which they had with them, but the natives claimed that their iron was superior to that of the white man. This might easily be the case because in the method adopted by the natives, and in these very old furnaces, the heat was not sufficient to reduce the impurities contained in the ore, such as phosphorus, and as they used nothing but charcoal as a fuel they were not bothered with sulphur. The iron they made was therefore probably softer, more malleable and more weldable than that which the British gave them, which was made by the ordinary puddling process from cast iron.

A modification of this crude furnace is illustrated in the Catalan furnace, a type which was used for centuries, in fact right down to modern times, at any rate until the last century. It had a small hearth, about 2ft. wide 3ft. long, and 18in. to 2ft. deep, and a blast of air was produced by water falling down a pipe, so that air was drawn in. Charcoal was used as a fuel. A mixture of charcoal and ore was put in at the top, and they continued blowing until they got a sufficiently large bloom of iron, which was picked out and raised to welding heat on other fires and then hammered into a rough bloom. That type of furnace was used, as I have said, until comparatively recent times both in America and in Europe. That method of extracting iron, however, only takes out about half the iron in the ore, and the other half practically forms the slag, by which the impurities are carried off. These slags are very rich in iron, and I might mention that cinders from old Roman furnaces were used in the Forest of Dean as a source of iron for many years, and since I have come to this country I have had samples of cinders from old native workings sent to me for analysis which have shown about 50% of iron with about 20 to 25%

of silicious matter, and some day we may possibly use this stuff as a source of iron in this country, if there is a sufficient quantity of it.

While the Catalan furnace was still being largely used on the Continent of Europe, another one, called the Stukofen, was used in Germany, and may be considered as the forerunner of the blast furnace proper. The method of working this furnace was to fill it with charcoal and blow until a good heat was obtained, then putting in a mixture of charcoal and iron ore, continuing to blow until there was a sufficient bloom of iron in the bottom of the furnace, when the breast of the furnace was taken down and the bloom was drawn out. There is something humorous to our minds in the idea of taking out the front of the furnace in order to remove the charge. That is the last thing you want to do. In a furnace of that description it is quite likely that by an accidental overcharge of charcoal, or with very easily reducible ore, or through leaving the charge too long in the furnace, it would absorb a certain amount of carbon, and the charge would then melt and cast iron would be discovered. At any rate there is no direct evidence as to how cast iron was discovered, but it came into use in England about the middle of the 16th century.

The iron trade in England increased to such an extent that the demand on the forests for charcoal became excessive, and the people were becoming alarmed about the supply for firewood and for shipbuilding. Acts were passed in Parliament restricting the use of charcoal for smelting purposes, particularly within 16 miles from London, because it was feared there would soon be none for domestic purposes. This restriction caused the iron trade to decline until the first epoch-making event occurred in the reign of James I. Dudley started experimenting with the use of mineral fuel, that is, of coal in preference to charcoal, and like all pioneers in the iron trade he had a rough time. The iron trade in England at that time was located in the South of England, in Suffolk and neighbouring counties, and if the idea of using pit coal was a success it practically meant that the iron industry would be taken away from there and carried to where the coal was available. Therefore the charcoal iron masters fought to get Dudley's licence cancelled. He finally started again in another part of the country and produced as much as seven tons

in one week, which I think was greater than had been produced in any charcoal furnace.

At the commencement of the 18th Century another man came into the field in the person of Abraham Darby. He worked on Dudley's experiments and charged his coal in pretty much the same way as the charcoal burner charged his pile of charcoal. He was successful, and erected furnaces at Coalbrook Dale in Shropshire. That was the death-knell of charcoal as a fuel for blast furnace work.

Developments took place during that century in every department of metallurgy, and by the beginning of the 19th century blast furnaces were about 20ft. high and produced about 20 tons a week. There was no very great development until about 1828, when a very important discovery was made. This was the discovery of the hot blast. Previous to that time it had been noted that blast furnaces worked better in winter than summer, and it was concluded that the colder the air the better, and attempts were made, I believe, to make the air colder in summer. This is an instance of where an outsider had probably a better chance of bringing forward an entirely new idea than one who had been brought up in the trade. Because it had been drilled into the minds of those who were brought up in the trade that cold air was the best thing for the furnaces, when a man proposed to put in hot air he was looked upon as a lunatic. When, however, the idea was tried in the furnaces on the Clyde the result was very surprising. After a few experiments it was found that by burning half a ton of coal outside the furnace and by the heat produced by that half ton a saving of three tons of coal inside the furnace was effected. The benefits of the hot blast were so undoubted that the system was rapidly adopted in iron works all over the country. Strange to say, however, the iron-masters were not inclined to pay the inventor, Neilson, anything for his patent. He went to law, and they fought him through the Courts, one of the arguments used by them being that one cannot patent an idea. He had not taken out a patent for an appliance, but for the idea of the hot blast. However, the Courts upheld him. The furnaces gradually increased in size until about 1845 they were using a hot blast of about 650 degrees temperature, and producing 120 tons of pig iron per week, and by 1855, when the temperature increased to about 800, they had reached

220 tons a week, while as the temperature went up the consumption of fuel went down very considerably. For instance with the cold blast they were using about 120 cwt. of coal for every ton of pig iron produced. That was coal, but of course it was turned into coke. With the temperature at about 600 they were using something like 85 cwt., and when the temperature was raised to 800 it dropped to about 60 cwt.

Just about this time a type of furnace was used in Staffordshire with an open top, and it was charged with what we call coco pans. The Black Country was therefore rather an awe-inspiring sight at night time with flames arising from the furnace tops. The amount of heat going to waste from the tops of the furnaces was such as to soon claim attention, and a Frenchman by the name, I think, of Dufré, proposed the utilisation of the waste gases from the tops of the furnaces for the purpose of fuel. It was a man named Perry, of Ebbw Vale, South Wales, however, who put the idea to practical application. Perry invented the closed type of furnace, which practically is the one in use at the present time. His device was a cup and cone, or bell and hopper, arrangement. The cup is built into the top of the furnace, and the bell is up against the side so that it closes the top and the charges are dropped into the space between the bell and hopper, and when the charges are dropped all round they release an apparatus that controls a lever, and the bell drops into the furnace about two feet and the charge slips off the bell and falls into the furnace. The whole apparatus is quite simple and very effective. A few modifications have been introduced, but even in some of the biggest furnaces in England and America at the present time that simple arrangement of Perry's is still in existence.

This saving of waste gases was important, because there is about 25% by volume of combustible matter in the waste gases from blast furnaces, and these gases were used for heating hot blast stoves, which immediately saved a lot of coal. After the stoves are satisfied there is still a surplus sufficient to supply the boilers, so that in the case of a plant consisting of, say, three furnaces, where all the gas goes into one common main, there is sufficient waste gas to supply all the requirements of the furnace—that is to say, the only fuel used is that which goes into the furnace itself. Sir Lothian Bell, about 1880, made an estimate that 1½

million tons of coal a year were saved by the utilisation of the waste gases of blast furnaces, and since then of course the saving has become very much greater.

The next thing of importance was the invention of the firebrick hot blast stove. Up to this time the hot blast stoves in use had been made of cast iron pipes—the type that was mostly in vogue about 1850. Several pipes were placed in rows in an oven which was fired by waste gases, or which could be fired by coal, and the blast went up and down the inside of the pipe while the flame played on the outside, and a very regular temperature was raised in this way, 800 to 900, and sometimes 1,000 degrees, being obtained. As the benefits resulting from high temperature blasts were noted it was concluded that by getting higher temperatures still more fuel would be saved, but beyond 1,000 degrees the wear and tear on the pipes was found to be very excessive, demanding extensive renewals and repairs to the stoves. This induced Cowper and Whitwell at the same time to invent the firebrick stove, although previous to that time Sir Wm. Siemens had invented the regenerating system.

A firebrick stove is formed of a shell of steel plate made gas tight, and lined inside with about 18 inches of firebrick. The diameter is about 22ft., and the height 70 to 100ft. The combustion chamber is made on one side and the rest of the stove is filled up with a chequer work of bricks. The method of working these stoves is as follows—A gas valve on one side is connected with the gas main from the furnace, and the gas is passed in from the bottom of the stove where it meets with air for combustion. The flame produced then travels up the chamber and is turned over by the dome and branches out through the chequers, passing out through the valve into the chimney. When the stove is sufficiently hot the inlet is turned off, the chimney valve is shut, and the cold air from the separate blowing engine is turned in from the end of the stove, and travels up in a reverse direction to that which the gas had previously taken, it passes up through the chequers and down through the combustion chamber, and then out through the hot blast valve, and in that travel the temperature is raised to anything up to 1,500 degrees Fahrenheit. The average temperature raised in America is 1,200 degrees, and it is a not uncommon thing in blast furnaces at the

present day to see a cast iron pipe red hot with the heat of the air that is coming in. These high temperatures, as I have explained, decrease the fuel consumption, and indeed it would be almost impossible at the present day to work high capacity blast furnaces without these firebrick stoves. I should also mention that there should be at least three stoves to each furnace because the work is intermittent, that is to say, while one stove is blasting the other two are being heated up.

About the year 1850 the Middlesboro' district in England was being opened up by this industry, and furnaces at that time were approximately 50ft. high, and produced somewhere in the neighbourhood of 220 tons a week. In 1860 the Brothers Whitwell erected a furnace at Thornaby-on-Tees, 60ft. high and of twice the dimensions inside of those then in use. They were so successful that John Dunn built one 71ft. high, and the economy in fuel consumption was so wonderful that by 1870 all the little furnaces were pulled down and big ones erected, and furnaces even 103ft. high were built at Ferryhill, near Durham, but those were not a success. Further it should be remarked that the blast furnace was made a lighter construction by using steel plates resting on cast iron columns instead of being a solid structure of masonry. This make of furnace ran up to as much as 560 to 600 tons a week, and this district was ahead of any other in the world as far as blast furnaces were concerned.

Then about 1880 the Americans started. The iron trade in America had reached a fairly large stage by that time, and was increasing rapidly owing to the tremendous demand for steel, and they thereupon drove their furnaces harder. In 1890 they showed furnaces which were making over 320 tons a day with a coal consumption which compared well with that of a slow-driven furnace. Our iron masters then saw that if they wanted to drive the furnaces harder they must increase the size of the hearth—that is where the blast enters and where the coke is burned. A certain sized hearth will only consume a certain amount of coal per minute, and to drive the furnace harder it is necessary to consume more fuel. So they increased the size of the hearth and left the body of the furnace very much the same as was in use in Middlesboro' at the time, and by this means obtained their increased output.

By 1900 America had so developed fur

naces that they had turned out as much as 750 tons in one day of 24 hours with a single furnace. This remarkable result was obtained at the Duquesne works of the Carnegie Steel Co.

They had discovered before that hand-charging was not capable of keeping up with such a rapid rate of output, and therefore they had to devise some mechanical means of charging the furnaces. The first thing they did was to run the charge up in skips and dump it into the top of the furnace, but they found that the furnace burnt out at the side opposite the skip, the reason being that the lumps of ore all dropped to one side of the furnace and blocked the channel; thus it drove more easily on one side than the other, and soon resulted in that part of the furnace burning out to the plates. They therefore looked round for a mechanical charging device. It must be here noted that there is a great deal in the way a furnace is charged. In the hand-charging method the barrows are taken round the top of the furnace and the furnace is charged in a regular and even manner. One of the first mechanical devices adopted was that invented by Brown, an American. At the top of the furnace he erected a funnel-shaped chute, and when the skip was hauled up the incline it was automatically tipped into a chute, from which it fell into the space round the bell. The doors as a rule stood open while the furnace was being charged, and when the charge was lowered into the furnace a mechanical arrangement prevented the gases from escaping. When the skip went back down the incline it brought into play a rotating arrangement which revolved part of the top about 87 degrees, so that when the charge came up the next one would be tipped at right angles. In other words, if the first was tipped east the next would be north, the next west, and the next south. That meant that in the course of 24 hours every part of the top was reached by the charges, and this type of mechanical charger was remarkably successful, the only objection being that it was very heavy. There was a large amount of heavy gear on the top and other devices have since been adopted which while more or less reducing this drawback are operated on the same principle. The result is that three men can practically keep a furnace going that is making from 500 to 600 tons of iron a day. It will be seen therefore that the development of the blast furnace during the last 50 years

has been enormous, and a tremendous amount of engineering ingenuity has been brought to bear on the subject.

Many minor developments have taken place with regard to blast furnaces which have assisted in making these extraordinary outputs possible, but I do not think I need introduce them here. But let me say a word about the consumption of iron. In the U.S.A. alone, in 1920, 36,000,000 tons of pig iron were consumed, which meant 70,000,000 tons of iron ore were consumed by American furnaces alone. Their resources must be feeling the strain of such an annual consumption as that. Now our resources in South Africa are practically intact, and we have large reserves. We have coal which makes excellent coke, and there is no reason that I can see why this country should not be able to make its own iron, not only for its own domestic requirements but also for export. The demand for iron will increase, and there is no reason why South Africa should not help to supply it. I need only quote the instance of Australia. Australia in 1907 started with practically the same size of furnace that is being put down at Newcastle, Natal, at present—that is to make 1,000 tons a week. That remained the only one in Australia that was working for some time, but in 1913 the same firm put down another blast furnace of about twice the capacity. Then the Broken Hill Proprietary Co., who had a very fine deposit of iron ore in South Australia, decided to enter the iron business on a big scale, putting down works at Newcastle, New South Wales. They started in 1914, and have now three big furnaces, and the latest report in regard to the last one that was blown in is that it is producing regularly 500 to 600 tons of pig iron per day, and by the report for 1921 the Broken Hill Proprietary Works at Newcastle were producing 1,000 tons of steel ingots per day. The works at Lithgow, N.S.W., have for several years manufactured rails and sections to highest tests and chemical specifications.

The Australian Federal Government set aside the sum of £150,000 for the encouragement of the iron industry, to be given at the rate of 12s. per ton of pig iron manufactured entirely from Australian materials, and also 12s. per ton of steel manufactured from Australian materials. This sum was earned by the iron industry of New South Wales and assisted in establishing it on a firm footing.

Australia therefore has practically made itself independent of outside resources in regard to structural steel, and everything else except the fine steel which Sheffield produces. With regard to steel rails, bridge material, and plates, Australia is now practically independent of outside resources. In addition to the benefits that ensue directly from the starting of iron works there are the subsidiary industries which they draw around them. For instance, at Newcastle, Australia, there is a wire works for the drawing of fencing wire, a galvanising works to make corrugated sheets which are rolled from steel supplied by the Newcastle Steel Works, a nail works has been put down also, and several subsidiary industries have been started which are getting their supplies from the Newcastle Steel Works. So far as I can see, South Africa ought to establish an iron industry more easily than Australia. I was in the pioneering of the iron industry in Australia for about 12 years, and know what the conditions are. At the Newcastle works, for instance, their iron ore is brought from South Australia, 1,500 miles by sea. Their limestone comes from Tasmania, also a long distance by water. The reason why they went to Newcastle was because the coal was there, and it is always advisable, as far as an iron and steel works is concerned, if possible, to have it situated near the coal mines, because in the production of a ton of finished steel, coal is by far the largest item of raw material which is used. The works of D and C Hoskins Ltd., at the Blue Mountains have to bring fully half of their coke from New South Wales, 150 miles distant, and with a climb of 1,000 feet. They also bring their iron ore from New South Wales, over 100 miles distant, so they have succeeded in establishing an iron and steel industry under conditions which are certainly not more favourable than our own. If indeed they are as favourable as in Natal and the Transvaal. If Australia can do it, I am certain South Africa can, and I see no reason why she should not get to work at once and make this industry a complete success.

Prof. G. H. Stanley proposed a vote of thanks to the lecturer, and said he felt sure the meeting had listened to the address with the greatest interest and with considerable profit, and if the lecture only brought about some reawakening of interest in the development of our iron resources it would have served a very useful purpose. What

was said and done at these meetings was published outside and he hoped the public would take notice. Everything else was based on the iron industry, and one of the first and most important things was for a country to establish its own. A very little reflection would show that the essentials of modern civilisation—food, clothing, housing, and so on all depended on iron. To-day, the older civilised countries were using iron at such a rate that their sources were within a measurable distance of exhaustion. As Mr. Henderson had pointed out, Australia was an example of what a Colony had accomplished in this direction. Canada also had her own iron industry, and likewise such countries as China and Japan. But South Africa as yet had not got such an industry, although as they had heard to-night a start had been made at Newcastle, and he was sure they would all wish it success. Of course the consumption of iron in South Africa was small as compared with that of other parts of the world, particularly in comparison with the enormous quantities produced in the United States. Yet in 1913 there were imported into the Union over £5,000,000 worth of iron and steel manufactures of a kind, which could be partly at least made in this country by a comparatively small iron industry. Importation had grown rapidly since the war. Taking 1921, in the first six months nearly £7,000,000 worth of iron and steel goods were imported. That meant about £11,900,000 worth per annum, a considerable part of which was capable of being produced in South Africa. That ought to be sufficient inducement to make us look into this matter closely, especially when we found all the natural conditions favourable. There was plenty of iron ore in the country and good iron ore. Dr. Wagner has stated that South Africa is second only to Brazil in the extent of its iron resources. We also had plenty of coal, and coal that would make coke, and our limestone resources were apparently illimitable. In the Cape Colony, for instance, there are whole mountains of limestone suitable for the purpose. We also had sufficient labour, and although our rates of pay for white labour were somewhat high, that fact was counterbalanced to some extent by the lower rates paid to coloured labour, so that our labour costs altogether should not be more than elsewhere. Therefore, taking everything into consideration it ought to be possible for this country to pro-

duce pig iron as cheaply as any country in the world, not even excepting India, which was probably the cheapest iron-producing country in the world to-day. Of course we should require some assistance from the Government. That was always a vexed question, but Australia could not have done without such assistance, and we ought to expect the same help from our own Government. He had taken out figures regarding the iron consumption per head in some of the other countries of the world. In the four chief iron-producing countries the consumption varied from 21 to 33 tons per head per annum. Taking our white population as $1\frac{1}{2}$ millions, and assuming a consumption per head of one-third of a ton, which was the figure in the United States of America, our consumption would be about half a million tons, and this was likely to be exceeded in view of the industrial activity to which this country was looking forward.

The President said that they had that evening a demonstration of the extended interests of the Society, and he was pleased they could show an interest in an industry which he trusted would be far more important in this country in another ten years' time. The Society welcomed to-night one of the pioneers in that industry, and they were all obliged to that gentleman for having given a very interesting resumé of the history of the iron industry and of its possibilities in South Africa. He trusted that in a few years' time the Society might be engaged in discussing details and improvements in iron metallurgy as applied to local ores, just as they had done in the past in connection with the metallurgy of gold.

EXHIBIT OF MICROPHOTOGRAPHS OF VISIBLE GOLD IN BANKET ORE.

The President stated that he had an exhibit here to-night consisting of several microphotographs of banket ore, or rather of the occurrence of free gold in banket ore, particularly in connection with its relation with carbon. The Society was indebted for these interesting photographs to Dr. W. A. Caldecott, who had kindly loaned them for examination. The photographs in question had been taken by Mr. Phillip Argall, the well-known metallurgist, who was making a special study of the occurrence of free gold in various gold ores.*

THE ENDLESS ROPE HAULAGE AT MODDER EAST.

By J. CHILTON.

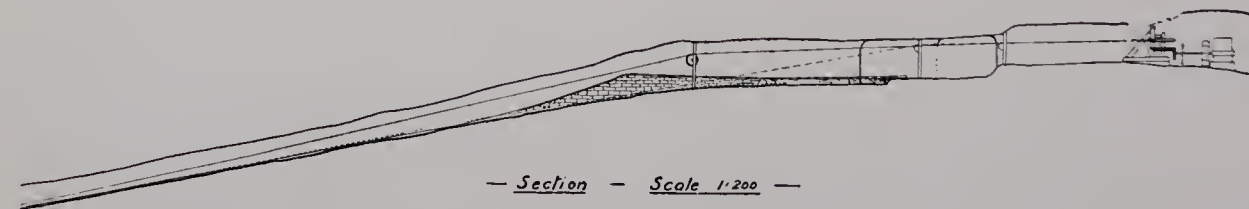
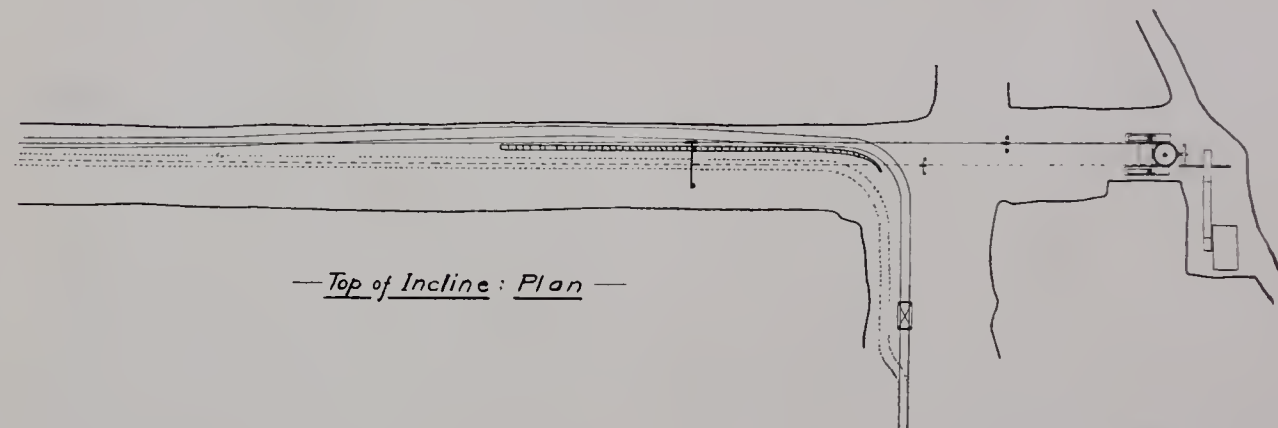
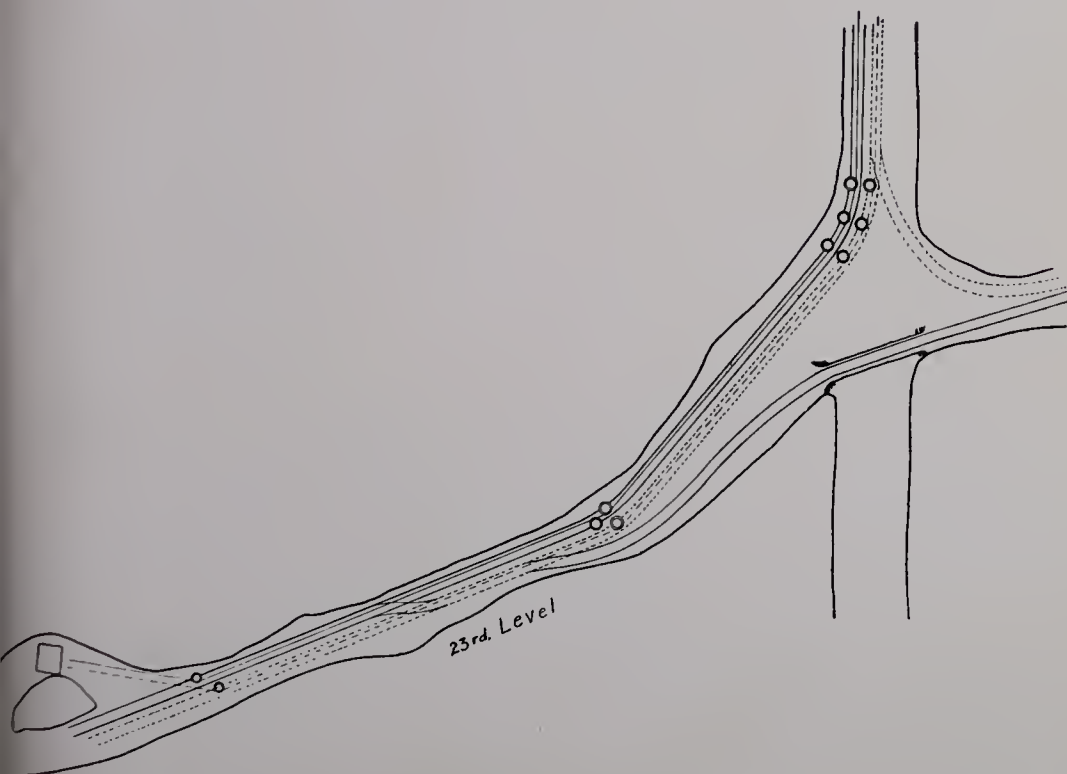
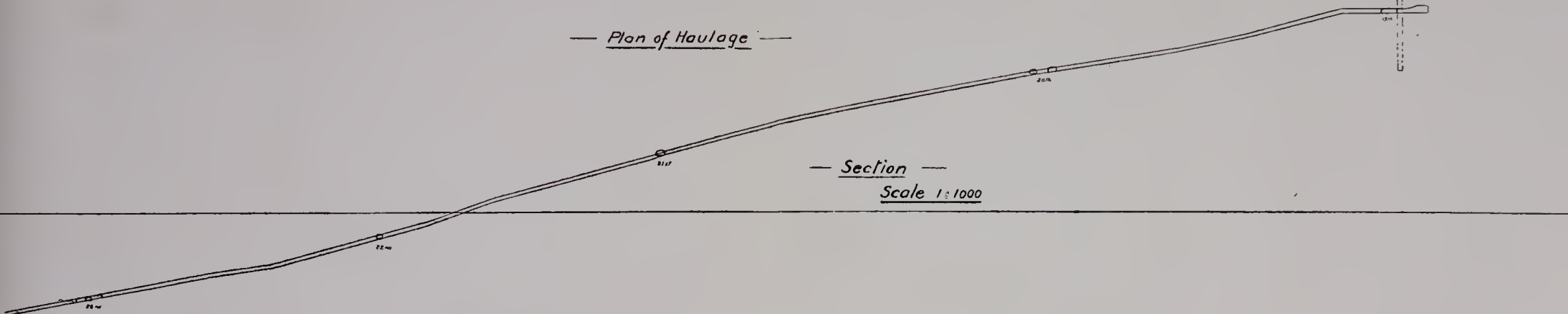
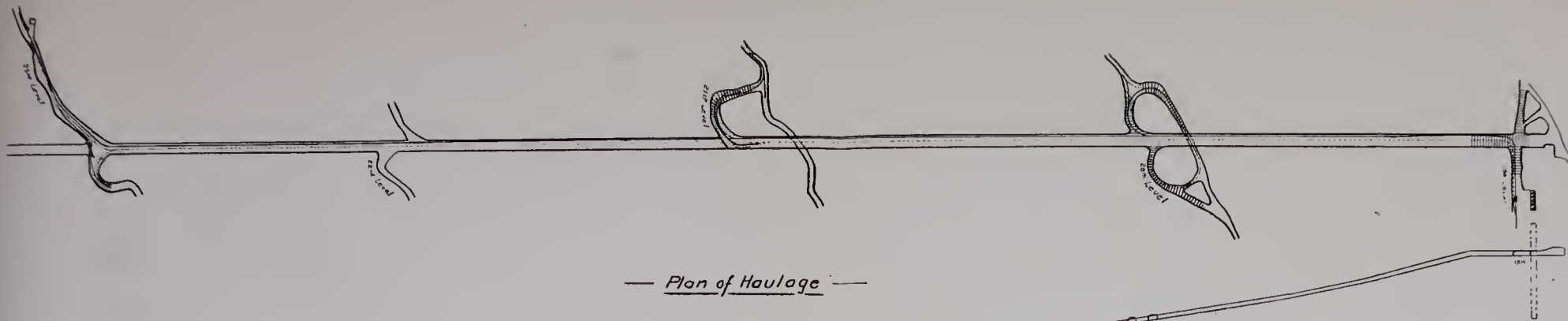
Underground haulage has received very little consideration from this Society, and for this reason the writer thinks some good purpose might be achieved by directing the attention of members to this important branch of mining activity. In making this communication it is not inferred that there is anything strikingly novel or extraordinary in the system described, but it is believed that it has merits that are not generally recognised in South Africa, and with the hope of arousing interest in haulage questions this description is put forward.

The endless rope haulage about to be described is in operation at the Cloverfield Shaft at Modder East, and is about 2,500 feet in length. Before the installation of the system the ore from the stopes and development drives was dealt with by air and electric winches, but it was found that this method was too slow and costly for a permanent plant and other methods of dealing with the ore had to be considered. The problem to be solved was to find the best method of raising 1,000 tons of rock per shift from the stopes and drives on the dip side of the main shaft, the upper landing being 470 feet vertically above the lower one. The average dip of the incline is about 13° , but near the bank head this becomes steeper, rising to 17° .

After much consideration it was decided that an endless rope haulage would be the best means of dealing with the requirements of this section of the mine, and the question then arose which was the best method of attaching the cars to the rope.

On the mines of the Witwatersrand, and particularly in the East Rand section, there are numerous types of rope clips in general use, and many of them have distinct merits, while none are absolutely safe. With the ordinary clip of the lever or screw principle, when ascending a slope, there is always the danger that the full trucks will occasionally break away and slip down the rope when nearing the top of a steep incline. This is due to the fact that the full rope near the bank head is of slightly less diameter than the same rope at the bottom of the slope, consequently most rope clips have to be tightened up when under this heavy strain. This entails extra expense in labour, and often damages the rope. To avoid these dangers and disadvantages at

* News has since been received of Mr. Argall's sudden death at Denver, Colorado. His valuable contributions to the science of Metallurgy will remain as a monument to his memory.—(Editor's note.)



Modderfontein East Rope Haulage

the Modder East it was decided to put in the chain grip attachment. This method of fastening is probably the simplest that could be employed, and where there is a steady and even pull against the load, it cannot be surpassed.

Subsequent events have shown the wisdom of this choice, for neither with the full nor the empty car has trouble been experienced due to slipping. The chains are attached to the front of the full car, and to the back of the empty. They are about ten feet in length with three-eighth links, and have a hook at each end. One hook is attached to the draw bar of the truck, then the chain is wound a few times round the rope and



hooked back upon itself. (See sketch.) One of the chief merits of this method of fastening is that the pull is on the draw bar, low down, and in the centre of the road, thus avoiding the side wear on the wheels, which is so marked a feature in some forms of endless rope haulages. The grip is also self-tightening and does not damage the rope. When the chain grip was under consideration it was recognized that there might be some trouble due to the twisting of the rope if great care was not exercised in splicing the ends, but this drawback was successfully overcome, and after the first few cars were driven up no further trouble was experienced from this source. Although there are two curves in the haulage, the chains and hooks pass round the sheaves without difficulty. The breaking strain of the chain is about three tons, and should a truck become derailed the chain breaks, thus avoiding damage to the rope. The diameter of the rope is seven-eighths of

an inch, and it travels over the tracks at the rate of two miles per hour. The attaching and detaching of the trucks at the three landings is done without interfering with the speed of the rope.

The haulage engine is driven by a 236 h.p. motor. This gives enough power for present day use and admits of further extension of the haulage should this be desirable. There is sufficient brake power on the engine to stop the haulage in ten feet in the event of derailment of cars or other accident. The rope passes three times round the slightly-coned drum; this gives sufficient friction to prevent slipping, while it allows a twisting movement in the coils. Trip switches are fitted to guard against overloading and consequent damage to motor.

On the haulage way there are four landings or points where trucks are fastened on and taken off. The main station is on the nineteenth level, and it is at this point that all trucks are dealt with. The track from the bank head to the trippers has a 3% grade, and trucks released from the rope run out by gravity. Empties return to the hanging-on point by the same means. The landing at the twentieth level is laid with a turn-out left and right, trucks proceeding south pass along a drive under the haulage. Empty cars are detached on one side, and full cars are connected up on the other. Switches are laid from the main track and, when necessary, a car is switched in, unhooked, and sent in the desired direction. A slight twist and a shake is sufficient to release the grip on the rope, and one native is all that is necessary to deal with the empties. On the opposite side of the track two natives attach the loaded cars. On the twenty-first level there is only one drive on the south side of the haulage way, so a somewhat different arrangement was necessary. Empties required at this station are switched out and move over a bridge which spans the main tracks, passing along to the siding about 200 feet distant. At both stations the full track is slightly dished to allow the loaded cars to pass under the rope, when attachment is easy. One from the twenty-second level is dropped through a vertical winch to a lower level and is loaded up from a footwall crosscut and attached to the rope at the twenty-third landing. Empties required in the north drives are switched in that direction, the remainder pass along to the main landing, where they are detached from the rope. It

will be noticed from the sketch given that there is a slight depression and deviation of the full track near the top. This was found necessary in order to remove the weight of the rope from the car when passing over the bend from the slope into the level landing. The curves on the haulage way are fitted with white iron pulleys, the lower flanges of which hold up the rope so that chains and hooks pass round without knocking or excessive friction.

Trucks loaded with timber, drills and other mining material pass freely up and down the haulage. When loading up explosives special precautions are necessary. The truck containing explosives is first fastened on to the rope, and about ten feet behind the guard truck is connected up. This acts as a buffer should a car be accidentally detached after passing over the run-away switch. Fortunately this misadventure has not yet occurred, but still it might happen. Special trucks for carrying men are in use. These are fitted with double chains and a safety trailer. The truck immediately before the man truck has also this safety appliance to prevent runaways. Owing to the slow rate of motion of the haulage it is quite easy to leave the conveyance while in motion so that accidents through travelling up and down are not likely to be numerous.

Trucks are attached to the rope at fairly regular intervals. The lowest landing spaces the cars every 80 feet, the next station attaches a truck between these, and the upper landing again divides this distance, so that the trucks reach the top about 20 feet apart. With this interval between each car the detaching of the rope is easily accomplished. Sometimes cars are sent up with only the length of the attachment chain between them; this is bad practice, but it causes no inconvenience to the natives employed releasing the cars. The capacity of the haulage is about 1,000 tons in eight hours. This figure has not yet been reached, but 90 trucks per hour has been accomplished over a consecutive period of six hours, and there is little doubt that with greater experience and larger supplies of ore the desired tonnage could be easily dealt with.

The successful working of any endless rope haulage system is governed to a great extent by the arrangements for taking in slack rope and keeping sufficient tension to prevent slipping on the driving pulley or

drum. Ropes stretch with use, and the weight of the load varies. The grip on the driving wheels slackens or tightens according to the position of the cars on a haulage way of varying grades, so that some method of keeping an even tension on the rope must be employed. On this system, the tension weight is at the lowest point in the haulage and consists of a loaded bucket containing about three tons of scrap iron. This moves between pulleys, and its average travel is less than twelve inches. To prevent violent surges due to serious accidents on the haulage, the balance weight itself is fitted with anchoring ropes which allow of a small movement beyond the ordinary travel of the tension weight.

The haulage is laid with 30 lb. rails in 30 ft. lengths with fish-plated joints, and a 2 ft. 6 in. gauge. It was originally laid with steel sleepers, but these were found to be unsuitable, and have been replaced by wooden ones.

The trucks used are the standard Rand Mines iron truck, with a carrying capacity of one ton. They are fitted with Rowbotham wheels, have a wide wheel base and substantial draw bar, and the centre of gravity is low so that derailments are reduced to a minimum.

Though the trucks on the haulage system only move at a very low speed, safety measures and appliances have not been overlooked. To guard against the possible danger of run-away cars various devices such as cutouts, run-away switches, and kick-ups were installed. The haulage way is lighted up from end to end and a roped-off travelling way has been made by the side of the empty track, and electric bells and telephones are in use at every landing. The immunity from accident which the haulage has so far experienced testifies to the effectiveness of these safety measures.

The system at the Modder East has not been long enough in operation to enable a close estimate of costs to be made. The life of the rope has not yet been ascertained, neither has the system been run to its full capacity, but the saving on the previous method is most marked, both power and labour showing considerable reduction.

In working the haulage only 14 natives and one European are employed. After allowing a reasonable interest on the capital expended, the cost per ton mile does not exceed 3.1d. Ordinary lashing and tram-

ming on most East Rand mines probably averages about 50d. per ton mile. The endless rope haulage costs on two neighbouring mines average 6.8d. over this distance, but it is only fair to admit that the capital charges in these cases were very high, as special haulage drives were necessary to deal with the tonnage required.

I have to thank Mr. H. Stuart Martin, who planned and supervised the haulage, and Mr. E. Pam, Manager of Modder East, for permission to record the salient features of this endless rope haulage system.

Prof. G. A. Watermeyer thanked Mr. Chilton for his paper, and assured him that papers of that description always served a valuable purpose because they gave us information on a subject which had been very little discussed. The wealth of detail on closer study made the paper still more valuable, and he considered a gratifying feature of the haulage system described was the measures which had been taken for safety throughout. He thought that would stand out as the best feature of the haulage system. With regard to the cost, they would be very pleased if, when Mr. Chilton replied to the discussion, he gave them a little more information.

Lt.-Col. E. Pam, in seconding a vote of thanks to Mr. Chilton, agreed as to the value of papers of that nature, and added that although here on the Rand we had been putting up haulage systems for 20 years, apparently nobody had taken the trouble to read about the practice during the last 50 years in the coal mining industry in England as set forth in various books and papers. When a new haulage system was being put in on the Modder East, Mr. Stuart Martin sent out one or two old issues of *Journal* from Home and pointed out this scheme of chain haulage. The chain attachment seemed simple, and after a very careful investigation on every mine on the Far East Rand it was adopted. The main point which Mr. Chilton had mentioned, but which he had not made quite clear, was the difference between the fixed grip which is attached to the top of the truck and the loose grip which can be obtained by a slack chain or rope. Obviously, if the *poke* is fixed on the truck it must be laid under the rope in its running position before the rope can be clamped on to it, and on an inclined haulage the truck might run back again. On the other hand with a slack chain and some sort of attachment the truck could be left standing in a

horizontal position at the side of the rope and at an angle to it. The truck is thus quite safe until it is actually attached to the rope. At the Brakpan Mine they had a similar scheme, using a chain and a patent grip, but after investigation it was felt that the ordinary chain was safer. As the rope gets to the top and there is more strain on it, it diminishes in diameter, and any fixed grip naturally becomes slack. The chain, on the other hand, works itself tight as the diameter of the rope decreases, so that the friction remains the same right through. Sketches would appear in the *Journal* which would make some of the details clearer, but to him one of the main points of interest in connection with the subject was the reversion to old coal mining practice.

DISTRIBUTION OF GOLD IN BANKET ORE CLASSIFIED PRODUCTS WITH REFERENCE TO MILLING AND CYANIDING OPERATIONS.

By F. WARTENWEILER, A.I.M.M.

(Printed in *Journal*, June, 1921.)

REPLY TO DISCUSSION.

Mr. F. Wartenweiler: I am indebted to a number of members for their contribution to the discussion on my paper. My original intention was to illustrate the distribution of the gold in the various classifications common to our milling and cyaniding operations. It was not to prove that the gold was principally associated with the pyrite in the same manner as silver is with galena, but I have endeavoured to show, within experimental limits, how it is physically associated.

The flotation method, with hand separation as a safety factor, served as a useful means of studying the extent of gold in the silicious gangue before and after cyanide treatment.

Mr. King has raised the pertinent point of the metallurgical and economic limits of grinding. I feel that this is too extensive a subject to be dealt with in a reply to discussion and suggest that he provoke full discussion by presenting a paper. In view of the development of the past two years and the trend of evolution to a fine pulp treatment by agitation on ores requiring

finer grinding, this subject might well be resurrected.

Referring to the limit of grinding if leachable sand is to be produced, it has been my experience that leachability does not entirely depend on the degree of comminution, but that the presence of rock constituents, such as silicates of magnesia, which on grinding assume a colloidal nature, has a serious retarding effect. To illustrate: On a plant where only 30 per cent. of the ore milled is treated as sand and where classification with water is considered good, the limit of leachability has apparently been reached and is extremely sensitive, yet the grading analysis of the sand discloses the following comparatively coarse grading:—

+60	+90	-90	-200
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3%	42%	41%	14%
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That grinding need not be limited or retarded by concern for leachability of sand is an advantage of which the metallurgists designing the projected new plants on Far East Rand ore are availing themselves.

With regard to the pannings I can assure Mr. Adam that only a small proportion of the pyrite—that too large to be lifted by the froth-forming bubbles—was collected by this method and practically no free gold. Anyone familiar with the difficulty of obtaining sight of free gold by panning, in a banket ore cyanide pulp or residue, will appreciate the low incidence of this panning factor on the accuracy of the classifications made.

Dr. Caldecott's contribution has supplied appreciated references of investigation carried out in the past on the same subject. It is perhaps unfortunate that the range of my investigation did not include tests on a mill-head sample. To arrive at the free gold in a mill-head or original ore I suggest that the gold usually recovered by amalgamation be taken into account. My deduction that the +200 mesh gold particles should be returned to the circuit for finer grinding refers to the usual cyanide pulp after amalgamation. The practical object of the investigation was narrowed to the study of extraction by cyaniding, and it is interesting to know the amount of unattached or free gold passing to the cyanide plant.

Mr. White's contention that on ores of the Eastern district, which differ from those of the Central area, we have not yet the exact correlation between the degree of

fine grinding and percentage of gold extraction, is difficult to refute in view of the meagre data published. In practice, when metallurgical methods are in a state of transition, when alterations to plant are being put into effect, and when the value of the mill-head is a variable factor, correlation becomes a matter of time and opportunity. The following tabulation, in which I have made an attempt at correlating grinding and extraction by selecting four consecutive months' statistics of such a plant, may also be unconvincing:—

Month 1921.	Tons Milled.	Mill Head Dwt.	Total Extn. per cent.	Cyan. Extn. per cent.	Cyan. Head Dwt.	Cyan. Res. Dwt.	Grinding per cent. 90 in cyan.pulp.
Sept.	25,000	8.83	93.78	89.60	5.23	.54	83.0
Oct.	27,000	7.86	94.79	90.28	4.29	.42	84.5
Nov.	24,600	8.54	94.36	90.26	4.82	.47	82.0
Dec.	24,200	9.08	94.87	91.59	5.60	.47	84.6

In practice the deleterious effect of the presence of the small quantities of finely ground nickel sulphide and arsenic sulphide (Orpiment) minerals* is doubtful on the ore referred to, providing sufficient precautions are taken in the precipitation section of the plant. It will be noted that the latter mineral was isolated and found unassociated with gold. I will endeavour to show a little later in my reply that encased gold in such an ore is a much more important factor.

I do not hold that the method of separation described in my paper is perfect, but that it does indicate the distribution of gold within such classifications as (1) free gold—that amalgamable with mercury, (2) gold within or attached to pyrite, (3) gold in the silicious and argillaceous gangue. The error due to the adherence of particles of gold to silicious gangue is apparently small. Mr. Adam's contribution to the discussion in effect replies to Mr. White's apprehension about the method employed. The writer is not clear in his own mind how roasting to a magnetic pyrite, a step which is apt to alter the physical structure of the ore and the original pyrite, will present a more accurate method.

My thanks are due to Mr. White for deducing from Charts, Refs. (11) and (12), that the percentage of extraction of gold in the finer ground divisions, -90 mesh and -200 mesh gradings, is greater in the pyritic portions than in the gangue, leading

* "Analysis of a Far East Rand Ore." by F. W. Watson. *This Journal*, May, 1921, p. 197.

to the conclusion that the gold is more intimately enveloped in the latter.

More recent investigation on slime residues from the more refractory Eastern district throws light and emphasis on this point, as shown in the results disclosed by tabulation:—

Grading:	-90+200 mesh.	200 mesh.	Composite
Per cent. by weight	16.6	83.4	100.0
Assay dwt. . . . .	.38	.28	—
Assay per ton original	.063	.233	.296
Encased Gold:			
Dwt. per ton . . . .	.25	.19	—
Dwt. per ton original	.042	.158	.200
FeS ₂ by S. determination:			
Per cent. by weight	.39	1.57	—
Per cent. by weight			
in original . . . . .	.065	1.309	1.374

It will be noted that of the 296 dwt. gold content of the residue the -200 mesh grading contains the large portion, or .233 dwt. per ton, and of this .158 dwt., or 67.8%, is encased or insoluble in aqua regia. Of the original residue, 20 dwt., or 67.5%, is encased. The 200 mesh division contains by far the largest proportion of the FeS₂ (1.57%), yet its encased gold is in about the same proportion as that of the -200 mesh grading, 67.8%, and 65.7%, respectively. The free gold and that within the fine ground pyrite has obviously been less resistant to cyanide attack than that encased in the silicious matrix. The remarkable feature appears to be the considerable gold which persists in remaining encased and to free which or render attackable presumes super classification and grinding to a degree of pulverisation which will seriously affect the mechanical efficiency of tube milling.

A RESUME OF STANDARD METHODS IN SAMPLING, ANALYSIS AND CLASSIFICATION OF COAL.

By A. TREVOR WILLIAMS, M.Sc., B.A.

(Printed in Journal, July, 1921.)

FINAL DISCUSSION

Mr. J. O. Braidwood: I should imagine from the first paragraph of Mr. Williams' reply that his feelings have been inadvertently hurt by something I said¹ if so I must express my sorrow and trust that he

will take the discussion in a friendly spirit. Further, I have not attacked his work, or the work of trained scientists, in a derisive manner because they were trained scientists, but because I disagreed with what was published; also I conclude that anything one publishes is open to criticism; otherwise any individual opinion published without criticism would certainly be held to be the opinion of members of that institution.

Mr. Williams, I think, is unaware that the South African Engineering Standards Committee published methods of sampling in 1912; I was a member of that Committee and placed before the technical gentlemen who composed it the method which I had had in use since 1908. We have again appointed a Special Committee on Coal under the auspices of the British Engineering Standards Committee, South African Branch, which has met, and will, meet again to revise and republish our standard methods. This is what might be termed entering our second stage, after about nine years of experience, which I think is somewhat different from what Mr. Williams would have us understand is the case in England where matters are of a more recent date.

We have seen a leaflet published by the Board of Trade, and we do not know if the Board of Trade is going to publish the entire report. If so, we might be expected to run things on the same lines, such as sampling a mine by means of pillars cut from the face or taking samples of coal of 39,000lbs weight, consequently we would rightly enquire, who pays?

I want Mr. Williams to appreciate the fact that I do not doubt that equally good results may be obtained by his methods, but I regret I am obliged to adhere to the tenour of my previous criticism with regard to the waste of time or money if adopted as compared with the methods in use here.

I feel that before proceeding with a reply to Mr. Sinnat's remark² on my contribution to the discussion that it would be better to say that I borrowed and have read Bulletin No. 2 of 1919 and No. 4 of 1920, but returned them after making a few

¹ This Journal, Feb., 1922. ² *Ibid.*, Sept., 1921, p. 36.

³ This Journal, Feb. 1922, p. 158.

extracts. I noticed the preface of one of them, written by Mr. Burrows, a sentence which read as follows:—"It is a matter of some regret that we are compelled to look to America for standardised methods for the valuation of coal." I am in full agreement with Mr. Burrows in so far as the regrets he expresses, but I do not agree that we are compelled to go to America for standardised methods for the valuation of coal. It reads as if the matter was beyond the capabilities of British scientific and commercial men.

With regard to the third paragraph which states that the value of the small coal is necessarily inferior in value to large coal, it must depend a good deal in what part of the seam the undercut is made. If there is no undercutting and the coal is blasted out of the solid this will again make a difference in the value of small coal. There is no rule that small coal must necessarily be of a lower calorific value than larger coal; it is usually so here, because the seam is undercut, in most collieries, in lower value coal, or bands where this occurs, and not as a rule on the floor line, where in most of our collieries the best coal is situated.

My point is, with regard to the quantities of large and small coal, that, if the sample is properly taken, the proportions of each should automatically be correct, the estimation of the large and small coal or impurities should be quite unnecessary, when taking a sample, if it be properly taken on a sound system.

I have not yet read the classical paper by Bailey, which I conclude is a treatise on sampling for various materials and general purposes, but I fail to see how the systems we have in use could be simplified; the results obtained by personal experience, and experiment, over a long period are our justification for a system designed and used for coal only. I see no reason for a change.

Referring to Mr. Sinnat's description of my remarks regarding a 39,000lb. sample as caustic and misleading I can only add that there seems to have been a sacrifice of economy, but the object of the sacrifice is not clear to me.

I have nothing to add to my remarks on the system of cutting a pillar of coal out of a seam. I still think it a waste of time and unnecessary labour except as a means of doing the work in comfort in the office rather than in the mine. I note that the pillar is cut by a collier at a cost of from £1 to £3.

and takes approximately a shift. In this time I should require five or six completed sub-divided sections, with a complete set of notes on the seam and other information. If this pillar of coal is required for exhibition purposes, as a traveller's sample, or a Board Room ornament, I can quite appreciate its value as worth its cost, but as a system for mine sampling, as I concluded it was intended, I unhesitatingly condemn it, except if it be necessary for special laboratory research work, which was not mentioned as the special object of this class of sample.

I note that Mr. Sinnat states that in his opinion "it is the only manner in which a seam can be investigated." Since 1908 I have carried on the investigation of seams, valuation of mines, etc.—a large number of reports having been written, entirely based on the system I have in use—without ever having had occasion to resort to the pillar system. The managers of these mines have in many instances stated that the figures handed to them represent the true value of the seam in their mine, but in no instance has the accuracy or the deductions made from the information obtained been either questioned or disputed, the output having confirmed my results provided the coal has been properly cleaned.

I do not dispute with Mr. Sinnat that his pillar system will give accurate results, but I consider it unnecessarily elaborate as a sampling method. I can get a very reliable and complete set of samples and other data in $1\frac{1}{2}$ to 2 days, of a colliery with an output of about 80,000 tons per month, provided that the working faces are not more than $1\frac{1}{2}$ miles from the shaft.

With regard to Mr. Sinnat's remark that "the examination of the seam is quite distinct from the valuation of the output of a coal mine," I would point out that here the seam is examined and notes made at the same time that the sample is taken. It is possible that the word "examination" used by Mr. Sinnat may mean extensive research work of an original nature, and not a classification of the varieties of coal composing a seam coupled with records of disturbances, faults, etc., which are noted in the vicinity of the place where the sample is taken.

With reference to my previous remarks regarding sending a 40 lb. sample to the laboratory, I meant that a sample can, and should be, reduced to about 5lbs. to send to the laboratory, and unless it is intended to carry out extensive analyses a 2 oz.

bottle full is sufficient to keep for reference.

Unfortunately we have been unable to educate the powers that be here to the advantages of research work on coal: 1 50 of a penny per ton would be of some use and amply repay the expenditure.

With reference to the last paragraph in Mr. Sinnat's contribution to the discussion it contains a wish which we most heartily applaud, namely, that we should be able in the future to have our own research association. To this I would add that we should welcome the great assistance that would result if Mr. Sinnat took an active part in it.

In conclusion I feel that the discussion resulting from Mr. Trevor Williams' paper has shown us that what suits one country, its conditions and products, does not necessarily suit another, although the product may be classed as similar. At the same time I would offer Mr. Sinnat my apologies for anything contained in my discussion which from his side of the world he may consider unjustified, and I trust that should I have the good fortune to meet him, or to be able to render him any assistance, he will feel that it is with the heartiest good will and to the best of my ability.

WASTE ROCK IN ORE MILLED

By W. A. CALDECOTT, D.Sc.

(Printed in *Journal*, October, 1921)

REPLY TO DISCUSSION

Dr. W. A. Caldecott: I am obliged to Prof. G. A. Watermeyer for giving me a more logical form of the equation shown in my paper, and I also appreciate Mr. H. A. White's endorsement of the importance of the working cost per ton of reef mined.*

Following on the lines set forth in the paper the question of sorting out clean reef for specially fine crushing appears worthy of consideration in certain cases. This principle of adopting separate treatment for a high-grade sorted product is common in other branches of metallurgy notably with galena ore, but it is also practised elsewhere in gold metallurgy, as illustrated by the following quotation from p. 99 of Ward's "Theory and Practice of Ore Dressing" (1915):

"Ore sorting can be practised with one or two ends in view. The first is to effect

a concentration by hand, the concentrate or shipping ore being directly removed by hand and routed to some convenient point for shipping. The second end, which can be effected by sorting, is to raise the grade to a more or less degree by removing by hand worthless, or nearly worthless, pieces of rock. The first is the more important and the end for which sorting is most commonly conducted. In the Cripple Creek District surface sorting is universal, the worthless or very low grade ore which results from screening out the rich fines, being picked over by hand for large pieces of value, the criterion for removal being any appearance indicating vein material, drusy surfaces of quartz, or other minerals, narrow vuggy cavities and, of course, any shewn of telluride minerals. The fines and large rich pieces go to the cyanide mills and smelters, and the balance to waste. The loss in waste is comparatively small, and the fines and sortings carry practically all the gold, and as about one-half of the ore is removed in the form of fines and rich pieces, the shipping ore is about twice the value as that hoisted from the shaft."

As applied to Rand blanket probably not more than 10% of the total ore milled could be sorted as clean reef and crushed to the economic limit of fineness in a portion of the crushing plant, allocated to the purpose and with separate ore bin and tube-mill circuit. With clean reef assaying from 20 dwt. to 30 dwt. fine gold per ton, this procedure would probably involve actual sliming, say, to 90-200 mesh, and the additional expenditure involved by sorting and finer crushing should be warranted through each 1% more gold in the clean reef exposed and extracted representing twice or thrice as much value as 1% on the average value of the total ore milled. In a large plant the additional profit might amount to several thousand pounds yearly.

Calculation will show that the desirability of this course increases with an increasing ratio of waste to reef in the total ore milled, as well as with the increasing assay value of the clean reef. Hence the method is unlikely to be useful when wide reefs of low or medium grade are mined, but is specially adapted for narrow reef mined with much waste.

When applicable the practice of sorting would hence yield three products, namely waste (discarded), mixed reef and waste (crushed), and clean reef (finely crushed).

*See this *Journal* p. 98, December, 1921.

The additional expense involved should be offset to some extent by the slightly less degree of fineness required by the residual poorer mixture of reef and waste, and the final tailing pulp leaving the reef-crushing stamps and tube-mills could be allowed to join the tailing pulp from the rest of the crushing plant for common classification and cyanide treatment.

THE CORRELATION OF METALLURGICAL STATISTICS.

By H. A. WHITE.

(Printed in Journal, December, 1921.)

DISCUSSION.

Dr. W. A. Caldecott: The mass of figures in the paper is evidence of the prolonged labour involved in its preparation, and it constitutes a record of the first comprehensive application to local metallurgical problems of statistical methods such as are used in other arts and sciences.

Without discussing the general issues raised in the specialised field of the paper one or two points may be commented on. The author's striking experience, that in some cases surface sorting actually corresponds with a decrease in screen values, is obviously due to some factor other than the removal of a certain percentage of low-grade waste from a given tonnage of ore hoisted in one day. When sorting corresponds with lower screen values the average value of ore hoisted must be materially lower than when sorting is not practised.

The author's confession of past error (on p. 104) in regard to the percentage of —90 product in the tube-mill outflow hardly seems required, since with the same feed tonnage to the tube-mill the minimum of —90 product in the inflow naturally involves a low percentage of —90 product in the outflow. In other words, the general view that the percentage of +90 in the outflow should not be too low (say, below 50%), is really equivalent to the author's conclusion that the feed should contain as much as +90 as possible.

The stope widths necessary with narrow reefs referred to by the author come within the province of the miner, but investigation would probably indicate that on much of the Rand more waste than reef was being mined and milled, though this fact is not

obvious from the usual practice of reporting assay values of stopes instead of separately the reef and waste to be mined.*

THE COMBUSTION OF SOUTH AFRICAN COAL IN BOILER FURNACES.

By E. P. REIM, B.Sc.

(Printed in Journal, January, 1922.)

DISCUSSION.

Mr. Jas. Gray: Our knowledge of South African coals is so meagre except as regards complete analysis that any contribution which may stimulate discussion and throw light on the subject is to be welcomed. I feel, therefore, that we are under a great obligation to Mr. Reim for his contribution, and I hope the discussion will result in increasing our knowledge on what is one of South Africa's most valuable natural resources.

It appears to me that Mr. Reim has, by certain modifications, improved boiler efficiencies and in his paper showing how this has been done he has introduced a certain amount of extraneous matter which is entirely irrelevant. Many of his statements cannot be substantiated and others are in entire disagreement with generally accepted opinions of workers in this field, or are still the subject of investigation, and the last word remains to be said.

It is also a pity that the writer did not edit the arithmetical part of his contribution more carefully, for numerous errors are to be found, and they certainly do not help to a satisfactory understanding of the paper.

I propose to deal with the various matters raised in detail, and will follow therefore the scheme of the author.

Origin.—In considering the combustion of coal for any particular purpose a knowledge of its origin and mode of formation may be useful, but I think the usual procedure in the Transvaal is to design the plant according to the coal available, and I feel that this procedure must of necessity be the most common elsewhere. It is generally admitted that portions of plants, tissue, etc., are always found in coals when examined microscopically. Stopes and Wheeler† deal very exhaustively with this subject, and in their review of the literature on the subject point

* See this JOURNAL, p. 64, October, 1921.

† Monograph on "The Constitution of Coal."

out that wood, bark, cuticles of plants, particularly those covering leaves and young twig, spore coats, sporangia, seeds, soft walled tissue, etc., have all been identified microscopically in coal.

As far as I am aware there is little or no literature on the origin of S.A. coals, and the theories which have been applied to the formation of coal in European countries and America have usually been taken to apply to coal in this country. With reference to the heat accompanying the changes taking place in the formation of coal, Bone and other writers are of opinion that the temperature to which coal has been subjected has not exceeded 300°C ., a temperature which cannot be considered excessive.

Impurities—Mr. Reim's conclusions regarding the presence of sulphur in coal is, if I read correctly, that it is due to subsequent infiltration. As regards pyrites and gypsum this is probably the case, but not all the sulphur in coal is present as pyrites but a proportion which varies largely is present in the form of "organic" sulphur. Stopes and Wheeler state: "As proteins in a variety of forms are predominant in the living substance of the plant body (the protoplasm and nucleus of every living cell), a variety of nitrogenous and sulphur-containing products are to be expected in coal, though in very much less quantity than the celluloses, owing to their relatively small bulk in the living plant." I have found that in Transvaal coal the proportion of sulphur as pyrites varies from about 100% to 30% of the total sulphur, while "organic" sulphur varies from traces to 60%, sulphate sulphur due to oxidation and gypsum being present in negligible quantities when the coal is freshly mined. Gypsum is rarely present.

Combustion—To state as the author does that, "the oxygen in the coal is assumed to be combined with hydrogen in the form of water (which water must exist in the coal in a combined state, as it is not driven off by ordinary drying at 100°C .)" is entirely incorrect. What should have been said is, "The oxygen of the coal is assumed on combustion to combine with the hydrogen of the coal to form water." It is probable that some coals do contain combined water which is not regarded as moisture on drying at 100°C ., and consequently renders misleading the figure for volatile combustible matter

in a proximate analysis, but to say that all oxygen in coal is present in the form of water is absurd. Coal is known to contain celluloses, resinic and nitrogenous bodies, all of which are compounds of hydrogen, carbon, and oxygen, and these bodies contain OH, CO, and COOH groups. Investigation by the action of solvents on coal have been conducted in an endeavour to obtain these various bodies in a form which enables examination.

The calculations which follow this statement are vitiated in a slight degree by arithmetical mistakes as follows:—

Line 18, 2.16th of 10.00% = 1.25%, not 1.02, and consequently the hydrogen percentage becomes 2.55.

Page 118, line 25, for "8540" read "8562."

Page 118, line 26, for "2.78" read "2.55."

Page 118, line 26, for "1470" read "1347."

Page 118, line 27, for "1.55" read "1.50."

Page 118, line 28, for "10.070" read "9.969."

It is generally admitted that calculations of the calorific value of coals from the figures obtained on ultimate analyses give a fairly satisfactory result. If sulphur in the first instance is considered important why does the author, in the second instance, reject it and substitute nitrogen.

The author's statements regarding the behaviour of coal on burning in a furnace are certainly not lacking in imagination, and though his microphotographs may help him to visualise the changes which the coal undergoes, I must confess that I am unable to follow him. Volatile matter and fixed carbon are not definite chemical entities as he appears to consider. The statement, "Regarding the ash, if this is fairly heat resisting, such as that containing chiefly silica and alumina, and if it is compactly distributed, it will retain its original shape, etc.," conveys nothing to me.

In the arithmetical calculations which follow, I suggest the following alterations:—

Page 121, line 12, for "6645" read "6645."

Page 121, line 23, for "5060" read "5052."

Page 121, line 23, for "2800" read "2788."

Page 121, line 29, for "3550" read "3544."

Second column, line 29, for "1960" read "1954."

Second column, line 10, for "10860" read "10840."

Second column, line 11, for "5040" read "5036."

Second column, line 11, for "2760" read "2780."

First column, line 12, for "10860" read "10840."

Page 122, column 1, line 29, for "237" read "0.237."

Page 122, column 1, line 33, for "10850" read "10840."

Page 122, column 1, line 35, for "10850" read "10840."

Page 122, column 2, line 28, for "10530" read "10080."

Page 122, column 2, line 29, for "270" read "2.070."

And substituting the correct figure of $10080/2.07 + 86^{\circ}$ F. the temperature is 2735° C. and not 2860° C.

If the calorific value of the original coal is calculated from the formula, the figure obtained is 11825 and not 12280 (line 30), and the theoretical temperature of combustion is 2749° C. and not 2860° C. (line 32). These corrections may not affect the deductions made, yet they make the paper difficult to follow.

Storage.—To make the bold statement that "in 1909 Mahler* proved that when air is passed over dry coal, free from occluded gas, at as low temperature as 25 to 30° C., water, CO and CO_2 are formed," leads one to the conclusion that if such passage of air was continued indefinitely the coal would be completely destroyed. Bone (Coal and its Scientific Uses, p. 919, p. 158) says: "At temperatures below 80° C. the absorption of oxygen in the cases of a Durham coking coal and a Barnsley steam coal of nearly the same percentage composition was comparatively slow even when the coal was exposed to the gas at high pressures, and the absorption was unattended by the production of more than relatively very small proportions of oxides of carbon. In the neighbourhood of 80° C. the action became decidedly quicker, and above 100° C. it was marked by a regular and simultaneous production of the two oxides of carbon and steam, all of which evidently resulted from the decomposition of some unstable 'oxygenated' body (or bodies) primarily formed by the absorption of the oxygen."

Spontaneous Combustion.—I feel that to dismiss such an important subject as this in the space of less than a column is somewhat drastic. The author assumes that because Mahler found that oxidation of coal takes place at low temperatures (a statement which is not entirely supported by Bone), that this would apply particularly to coals high in volatile matter. What reasons has he for making this deduction? His reference at the end of the paragraph to Lomax does not support it as would appear from the statement, "and these are not always those with the highest percentages of volatile matter or pyrites."

The Microscopic Examination of Coal.—Mr. Reim appears to labour under the idea as I remarked before, that fixed carbon and volatile matter are definite chemical entities. I am satisfied that he cannot by polishing and etching or heat tinting, or any other means, produce a section of coal which will show under the microscope fixed carbon or volatile matter. His statement that one can estimate the suitability of coals for different purposes by this means is absurd.

Notices and Abstracts of Articles and Papers.

CHEMISTRY

DETERMINATION OF PHOSPHORIC ACID AS MAGNESIUM PYROPHOSPHATE.—A critical review of previous work on the estimation of phosphoric acid or magnesium by precipitation as magnesium ammonium phosphate and subsequent ignition of the precipitate. Neubauer's method and the use of a single precipitation at a low temperature are not to be recommended, as accurate results are obtained only under special conditions. The double precipitation method gives good results provided that the first precipitate is dissolved in not too little hydrochloric acid, only Cl⁻ and NO⁻ anions and no large quantity of alkali cations are present during precipitation, and that the second precipitation is carried out by rapid addition of 10% ammonia solution. Schmitz's method is the only one which under special conditions, gives a pure magnesium pyrophosphate, and which gives accurate results under widely varying conditions.—D. BALAREFF, Z. anorg. Chem., *Journal of Society Chemical Industry*, August 15, 1921, p. 562a. (A.W.)

DETECTION OF LEAD IN PEATY WATERS.—The brown colour of certain peaty waters interferes with the detection of traces of lead by the alkaline sulphide test. To eliminate the colour the water is treated with a slight excess

* Mahler on passing air over 150 grams of finely-divided coal for 30 hours at a temperature from 25 – 30° C. obtained 100 c.c. CO_2 and 2.88 c.c. C.O. J.S.C.I. 1910, p. 744.

of permanganate, then rendered ammoniacal, and kept for forty-eight hours; the precipitate which forms contains the whole of the lead and may be collected on a filter, dissolved in hydrochloric acid (a colourless solution results), and the solution tested for lead in the usual way.—**T. TICKLE**, Analyst, *Journal of Society Chemical Industry*, July 30, 1921, p. 526A. (A.W.)

SEPARATION OF SILICON, TIN, TITANIUM AND ZIRCONIUM BY SODIUM CARBONATE.—The mixed oxides are fused for three hours with six times their weight of sodium carbonate, the fused mass is boiled with water, and the solution filtered. The filtrate contains the silica and a portion of the tin, and these are weighed together after evaporation with nitric acid, the silica being separated subsequently by treatment with hydrofluoric acid. The insoluble portion contains the titanium, zirconium, and the remainder of the tin; it is ignited, fused with eighteen times its weight of potassium bisulphate, and the mass boiled with water containing nitric acid. Tin remains insoluble and is separated by filtration; the filtrate is neutralised, treated with hydrogen peroxide, and the precipitated zirconium separated and weighed. The titanium is then precipitated by ammonia.—**P. WENGER** and **J. MOREL**, Ann. Chim. Analyt., *Journal Society of Chemical Industry*, July 15, 1921, p. 492A. (A.W.)

THE STABILITY OF ATOMS.—The Mid-Victorian belief in the immutability of the atoms even when subjected to "the most drastic physical and chemical agencies available," had, of course, to be discarded at the beginning of the present century, when the spontaneous transformation of some of the heavier elements was established.

About the positively charged nucleus of the atom there is a distribution of enough negatively charged electrons to make the entire atom neutral. One or more of these may be detached without causing a lasting change in the atom. "In order to produce a permanent transformation of the atom it is necessary to disintegrate the nucleus." This is very small, having a radius not greater than 6×10^{-16} cm., but its constituent parts are held together by strong forces so that only "a few agencies are available for an attack on its structure." The alpha-particle is a very concentrated source of energy and, in the case of the heavier elements, one such particle out of 10,000 collides with the nucleus. "The case of the lighter elements, however, is much more favourable, for the repulsive forces are so much weaker that we may expect the alpha-particle to enter the nucleus structure without much loss of energy."

When hydrogen or a hydrogen compound is bombarded by a stream of alpha-particles it sometimes occurs that a hydrogen atom is driven ahead with such a velocity that it causes scintillations upon striking a zinc sulphide screen. The maximum range of such H-atoms is 20 cm. under certain conditions. When nitrogen or dry air is bombarded in the same manner swiftly moving H-atoms appear, but with a range of 40 cm. This difference of range renders it impossible to ascribe the H-atoms to the presence of traces of hydrogen or of its compounds in the air or nitrogen used. From

boron, fluorine, sodium, aluminium and phosphorus such swift H-atoms are ejected by the impact of the alpha-particles. The range of the atoms from aluminium is 80 cm. "It is of special interest to note that H-atoms are only liberated in elements whose mass is given by $4n + 2$ or $4n + 3$ where n is a whole number. No H-atoms are observed from elements like carbon, oxygen and sulphur, whose mass is given by $4n$." In the experiments cited only one alpha-particle in a million breaks up a nucleus.—**SIR E. RUTHERFORD**, *Journal Franklin Institute*, February, 1922, page 254. (J.A.W.)

SELENIUM AND TELLURIUM COMPOUNDS AS INTENSIFIERS OF GASOLIN.—Authoritative reports from the laboratories of the General Motors Company give information that by the employment of selenium oxychloride or diethyl telluride the efficiency of a given amount of gasoline can be doubled.

The data have been obtained by Midgley and Boyd. The tellurium compound was the most efficient, and is especially advantageous in eliminating the "knock" which is developed when a motor is labouring on a grade.

Victor Lenker states that if only one hundred of one per cent. should be used in gasoline the amount of tellurium required in the present use of gasoline in the United States will be 1,500 tons.

In 1920 it was ascertained that without further plant equipment the country could produce only a little over sixty short tons.

It will be necessary to find new sources of tellurium and also of selenium if these materials are to be extensively employed. A very important point will be the sanitary problems, which apparently have not yet been considered.

Selenium and tellurium compounds are mostly quite poisonous.—*Journal Franklin Institute*, March, 1922, page 290. (J.A.W.)

NEW METHOD OF HYDROGENATION.—Granichstaden and Sittig describe, in *Giornale di Chimica*, the use of a nickel-magnesium silicate as a catalyst of high power in hydrogenation, oils acquiring an unusual degree of whiteness at not above 40°C.

With most methods now in use dark oils must previously be bleached if desired to be of good colour, but with the new process this bleaching is not required.

The catalyst is prepared by precipitation so as to secure as uniform a product as possible. The procedure promises to be widely used and is to be covered by patents.—*Journal Franklin Institute*, March, 1922, page 370. (J.A.W.)

PREPARATION OF CARBONATE FREE SODIUM HYDROXIDE.—Jacob Cornoz, of Ohio State University (*Journal American Chemical Society*, 1921, vol. 25, 2571) has devised the following technique for the preparation of a solution of sodium hydroxide free from carbonate.

Distilled water is boiled in an Erlenmeyer flask to remove dissolved carbon dioxide, then is cooled and covered with a layer of ethyl ether from 1 to 4 centimetres in depth.

Pieces of metallic sodium not exceeding 1 centimetre in diameter are dropped into the flask and remain suspended in the ether.

The water present in the ether slowly converts the sodium into sodium hydroxide, which passes into the aqueous layer.

When the proper amount of sodium has been dissolved, the greater portion of the ether is removed by means of a pipette, the remainder by boiling the solution.

The resulting aqueous solution of sodium hydroxide does not yield a precipitate with an aqueous solution of barium hydroxide; hence is free from carbonates.

Fire and explosions never occur during the preparation, provided the layer of ether be kept sufficiently deep so that the suspended sodium cannot come into contact with both the air and the water at the same time.—JACON CORNOG, *Journal Franklin Institute*, March, 1922, page 404. (J.A.W.)

RECOVERY OF ZINC FROM CYANIDE PLANTS.—A description of the Kominsky process for recovering zinc from waste solutions from cyanide plants. This process is in work on a small scale at Germiston, east of Johannesburg. The zinc-slimes obtained in the precipitation of gold from cyanide solutions consist of metallic gold in finely divided form, unattacked zinc, and some insoluble zinc compounds. After the mass has been filtered the solid mass is treated with sulphuric acid solution or with a solution of acid sodium sulphate. The gold remains unchanged by this treatment, but the zinc passes into solution. After the treatment with acid is completed, the gold is separated and sent to the smelting-house. The solution contains zinc in solution, and is at present run to waste. The object of the Kominsky process is to obtain the zinc in the form of pigment. The solution contains, as a rule, zinc salts equivalent to about 5% of metallic zinc, but, in addition, it always contains a small amount of iron salts which are present mostly in the ferrous condition, and the solution is always acid. For the production of zinc pigment it is necessary to remove the iron from the solution, because if this is not done the iron would find its way into the precipitated zinc compounds and would cause discoloration. The removal of the iron has been made possible by the Kominsky process. At the Germiston works the first step in the process is the control of the acidity of the solution; if the solution is too acid the acidity is reduced by the addition of lime, but care must be exercised that the acidity is not reduced too much. The iron in the solution is then completely converted into ferric condition by the addition of a solution of sodium chromate. As the ferrous iron is oxidized to the ferric state the chromate (or bichromate, since the reaction takes place in slightly acid solution) is reduced so that the solution now contains, in addition to sodium salts, zinc sulphate, ferric sulphate, and chromium sulphate. It is not advisable to use excess of sodium chromate, although a moderate excess can readily be corrected. To a small proportion of the original solution the requisite quantity (but no excess) of solution of sodium hydroxide is added. This precipitates impure zinc hydroxide. This zinc hydroxide is made into a thin paste, which is now added to the fully oxidised solution. The zinc hydroxide is added in considerable excess. The first action is that of the excess of acid present on the suspended

zinc hydroxide, whereby the solution is neutralized and a quantity of zinc sulphate equivalent to the free sulphuric acid present is produced and passes into solution. The zinc hydroxide then reacts in the neutral solution with the ferric and chromium sulphates, producing insoluble ferric and chromium hydroxides, which separate from the solution and an equivalent quantity of zinc sulphate passes into solution. The zinc hydroxide then reacts in the neutral solution with the ferric chromium sulphates, producing insoluble ferric and chromium hydroxides, which separate from the solution and an equivalent quantity of zinc sulphate passes into solution. The fluid is then filtered, and the clear filtrate obtained is a neutral solution of zinc sulphate and sodium sulphate. The sludge in the filter-press contains an excess of zinc hydroxide mixed with hydroxides of iron and chromium, and can be re-used as a precipitating agent until the zinc hydroxide is almost exhausted. The clarified solution containing zinc and sodium sulphates is now in a condition to be precipitated. The precipitation may be effected by means of a solution of sodium carbonate whereby insoluble (basic) zinc carbonate is deposited, or by means of solution of sodium chromate, in which case insoluble zinc chromate separates. The insoluble zinc salt is well washed with water to remove all the sodium salts, and it is then separated in a filter-press. The sludge in the filter-press is dried; at present the sludge is dried by exposure to the air, but this method is unsatisfactory and a dust-proof drier should be installed. The dried zinc chromate obtained in this way requires only to be crushed and sieved to be ready for use as a pigment, zinc yellow. In order to make zinc white (zinc oxide) the dried basic carbonate would require to be calcined in a calcining furnace, and in order to make a satisfactory pigment the calcined mass would require to be finely ground and sieved. The processes in use at the Germiston works are simple. The present capacity of the plant allows of the production of about two and one-third tons of pigment per day of twenty-four hours. The cost of the process will be determined largely by: (a) transport of the zinc-slime solutions to the works; (b) cost of reagents, sodium chromate, and sodium carbonate. There will be obtained as a by-product sodium sulphate in the form of a solution. Recovery of this salt (Glauber salt) in a useful form will entail evaporation or a system of evaporation followed by refrigeration. It may be added that, on the assumption that the zinc-slime solution obtained from the gold mines contain zinc salts equivalent to 5% of metallic zinc, each gallon of the solution would contain $\frac{1}{2}$ lb. of zinc, and from this would be obtained 1.38 lb. of zinc chromate (zinc yellow) with the aid of 1.25 lb. of sodium chromate. Or, if zinc white (zinc oxide) were made, then for each gallon of solution 0.81 lb. of sodium carbonate would be required and 0.96 lb. of zinc carbonate would be obtained, which would yield 0.62 lb. of zinc white. The consumption of zinc on the gold mines of the Witwatersrand is about 2,500 tons per annum. The major portion of this amount can be recovered.—*South African Journal of Industries* (reprinted in *Mining Magazine*, London), December, 1921. (F.W.)

A VERY SENSITIVE REAGENT FOR COPPER: THE KASTLE-MEYER REAGENT.—The Kastle-Meyer reagent, which is a 2% solution of phenolphthalein in 20% potassium hydroxide solution decolorised by boiling with zinc powder, gives a pink coloration with copper salts and is capable of detecting 1 part of copper in 100,000,000 parts of water. Four drops of the reagent are added to 10 cc. of the solution to be tested and then one drop of hydrogen peroxide (5-6 vols.).—P. THOMAS and G. CARPENTER, *Journal Chemical Society (compt. rend.)*, 1921, 173, 1052-1055, January, 1922, p. ii, 86. (R.A.C.)

THE USE OF MERCURIC NITRATE INSTEAD OF SILVER NITRATE IN THE ESTIMATION OF THE HALOGENS.—The method proposed by Votocek in which mercuric nitrate is used with sodium nitroprusside as indicator, gives very accurate results for chlorides (and for bromides, cyanides, and thiocyanates) if a correction is applied for the excess of mercuric salt necessary to produce a precipitate under given conditions of composition and volume of solution. Neither dilute acids nor the common metals except copper, cobalt, nickel and cadmium interfere. The method estimates accurately chlorides in conductivity water, and gives good results for as little as 9 mg. of chlorine per litre; it is suitable for the estimation of chlorides in urine.—I. M. KOLTHOFF and A. BAK, *Journ. chem. Soc. (Chem. Weekblad)*, 1922, 19, 11-10, February, 1922, p. ii, 159. (R.A.C.)

NEW METHOD FOR THE VOLUMETRIC ESTIMATION OF COPPER.—The salt $\text{CuSO}_4 \cdot 4\text{NH}_3$ is quite stable at the ordinary temperature, and is quantitatively precipitated from aqueous solution by addition of eight volumes of 98% alcohol. The precipitate after thorough washing with alcohol, is redissolved in water and titrated with N/10 sulphuric or oxalic acid, with methyl red as indicator.—S. MINOVIĆ and A. JONES, *Journ. chem. Soc. (Bull. Soc. Chim. Roumanie)*, 1921, 3, 89-93, February, 1922, p. ii, 162. (R.A.C.)

INDICATORS AND HYDROGEN ION CONCENTRATIONS.—Indicators are substances used to determine the end point of, or the completion of, a definite stage in a chemical reaction. They consist of an ever-increasing variety of bodies, the majority of which show the end of the particular reaction, the completion of which they are called upon to indicate, by the production, change, or disappearance of color. This present note deals solely with the class of indicators used in volumetric, and the use of the word indicator is intended to refer to one belonging to this class. These indicators are organic coloring matters, allied to the dyes, and are commonly stated to exhibit different colors in acid and alkaline solutions. An indicator, however, does not necessarily produce acidity or alkalinity, although all indicators will distinguish between a strong acid and a strong alkali; the change in color merely shows a change in hydrogen ion concentration.

According to the theory of electrolytic dissociation, when an acid is dissolved in water it is partly dissociated into hydrogen ions and anionic ions; it is to these hydrogen ions that

the acidity of the solution is due. In the same way a base dissolved in water dissociates into basic ions and hydroxyl ions; it is to the latter that the alkalinity of the solution is due.

The concentration of hydrogen ions expressed in terms of grams of ionised hydrogen per litre of solution is represented by the symbol $[\text{H}]$ or C ; thus $\text{Cn} = 10^{-6}$ means that in one litre of solution there is contained one-millionth of a gram of ionised hydrogen.

In order to simplify working conditions and to do away with the use of negative indices it is customary to state the hydrogen ion concentrations at which indicators show their colour changes in terms of what is known as the Pn values.

Pn is the logarithm of the reciprocal of Cn , i.e., $\log \frac{1}{\text{Cn}}$; thus if $\text{Cn} = 10^{-6}$; $\text{Pn} = 6.0$.

Pn is therefore the index of the H ion concentration with the sign reversed. The colour changes of indicators take place over definite ranges of H ion concentration. Methyl orange, whose range is from Pn 2.9 to 4.0, is red when the concentration of H ions is not less than $10^{-2.9}$. As the concentration decreases the colour of the indicator passes through orange until when the concentration becomes $10^{-4.0}$, the colour will be yellow.

No further change will take place no matter how small the hydrogen ion concentration, or acidity, may become. Methyl orange is therefore useless to indicate any other range. Phenolphthalein will indicate a change in hydrogen ion concentration from 10^{-8} to 10^{-10} ; but it will not indicate over the range of methyl orange, and so on. Pure water dissociates to a small extent into hydrogen and hydroxyl ions. This balance is readily upset by the presence of dissolved substances. The addition of acid increases the concentration of H ions and decreases that of the OH ions but the product of the two remains constant (10^{-14}). Alkali, on the other hand, decreases that of the OH ions. It is usual to state the acidity or alkalinity of all solutions solely in terms of H ion concentrations, and to ignore the OH ions, but as $\text{Cn} \times \text{Con}$ always equals 10^{-14} at 18°C the concentration of the OH ions may be calculated readily, if required.

Pure water is taken as the standard of absolute neutrality, as the concentrations of its hydrogen and hydroxyl ions are equal, $\text{Cn} = \text{Con} = 10^{-7.07}$ and $\text{Pn} = 7.07$, consequently all solutions whose Pn is less than 7.07 will be acid, and those with a Pn over 7.07 alkaline.

The Pn of solutions may be determined approximately by means of different indicators; thus a decinormal solution of ammonium chloride is all blue to methyl orange (Pn 2.9-4.0) and acid to phenol red (Pn 6.8-8.1), consequently its Pn lies between 4.0 and 6.8. It is found to be neutral to methyl red (Pn 4.2-6.3) thus further narrowing the range. Its actual Pn is 5.4. The exact Pn value is usually determined by comparison with so-called "Buffer" solutions. These consist of solutions of various salts to which varying quantities of acid or alkali have been added, and exhibit definite H ion concentrations, which, owing to the "Buffer" action of the salts, are not readily changed by traces of

impurities, and they may be relied upon as standards.

A series of test tubes containing buffer solutions of graduated Pn values, with the addition to each of the same quantity of an indicator whose Pn corresponds with the same range, will show a very gradual colour change, each shade corresponding to a definite Pn value. Thus, in order to find the Pn of any solution, it is only necessary to add the correct quantity of a suitable indicator, and compare the colour obtained with a series of buffer solutions containing the same quantity of the same indicator. By the use of carefully selected mixtures of indicators, it is possible to determine the approximate Pn of any fluid without the aid of buffer solutions. Such mixed indicators show a number of different colour changes over a large range. The average observer can recognise the six spectrum colours and their half-way shades with a fair degree of accuracy without a colour comparison, and if the colours assumed by the indicator are calibrated initially against buffer solutions, it follows that any Pn value within the range of the mixed indicator can be determined approximately at sight.

The author gives several examples of the method of choosing a suitable indicator for a given titration.—T. T. COCKING, *The Chemical Age*, January 28th, 1922, page 94. (R.A.C.)

MAGNESIUM CARBONATE AS A CLARIFYING AGENT.—The properties of light magnesium carbonate are quite unique. It is a very bulky, white, inert powder, whose particles are extremely finely divided, averaging usually about 1 micron in diameter (a micron is one-thousandth millimetre). These microscopic crystals have a very soft, smooth texture. Their composition is ordinarily assumed to correspond to the chemical formula: $1 \text{ MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 5 \text{ H}_2\text{O}$; but this will vary with the method of manufacture, and samples of this product manufactured on a large scale in America, by boiling a solution of magnesium bicarbonate, have been found to correspond more nearly to such a composition as that represented by: $11 \text{ MgCO}_3 \cdot 3 \text{ Mg}(\text{OH})_2 \cdot 11 \text{ H}_2\text{O}$, probably being composed of a mixture of magnesium carbonates of simpler molecular formulas. Light magnesium carbonate has an absolute specific gravity of only 2.18, referred to the density of water, and is, therefore, one of the lightest of mineral products, but further than this it crystallises in such a bulky snowflake-like form that the powder encloses about 7 times its own volume of air, so that it weighs only about 90 grammes per litre, or 5.5 pounds per cubic foot.

According to a communication from the Mellon Institute of Industrial Research, Pittsburgh University, to the *American Perfumer*, magnesium carbonate is quite insoluble in water, only about 0.035 gramme of the oxide dissolving in a litre of water. This amount is so small as to be absolutely negligible with regard to its physiological effect, or to any effect upon the qualities of the product being clarified. Magnesium carbonate does not impart any taste or odour to the liquid in which it is used, but the carbonate cannot be used in the clarification of any product containing

acids. In such a case, the liquid may be clarified by the use of magnesia before the addition of the acid to the product, as, for example, in the case of flavouring extracts for soft drinks to which phosphoric or citric acid is added.

The purely mechanical dirt and impurities suspended in these solutions may easily be removed by simple filtration, but this is not true of the resinous or colloidal impurities. When magnesium-carbonate powder is suspended in a liquor of this type it has the property of absorbing or agglutinating a large part of these colloidal impurities, so that they may be removed by filtration. Magnesium carbonate has also the property of breaking up emulsions of oils in water, due apparently to its greater absorption power for the oil than for the water, and this enables it to clarify solutions in which the cloudiness or lack of brilliancy is due to the presence of emulsified oils. A limited amount of the colour of tinctures and other preparations, whose excessive colouring is due to colloidal resinous substances, may be removed by the use of magnesium carbonate, but this material has very little absorptive power for coal-tar dyes.

It should be emphasised that it is not necessary to use a great excess of the magnesia powder to effect complete clarification in most cases, and large amounts simply add to the difficulty of filtration; usually from 0.5 to 1 per cent. of the weight of the liquid to be clarified is ample.—*The Chemical Trade Journal and Chemical Engineer*, November 12, 1921, page 589. (F.W.)

METALLURGY.

PRESENT DAY IRON BLAST FURNACE PRACTICE.

The state of practice is metallurgical rather than mechanical; the tendency is towards progress in the metallurgic side, the mechanical side having reached an advanced state. Metallurgical progress is taking place inside the furnace with the improvement of the slag and the rate of combustibility of the coke. Outside the furnace progress will be along the lines of proper ore mixtures limestone and character of coke. Limestone is more carefully chosen; the magnesia content of this, if kept below 8%, does not affect slag viscosity, according to Field. Careful sizing of the limestone, and in some instances washing, is practical. Opinions in regard to the best cokes vary greatly, and research is suggested. By-product coke is considered to be generally satisfactory and susceptible of production to most any specification.

The physical qualities of the iron ores are being improved by wet ore dressing, by roasting by nodulizing, sintering and magnetic concentration. Sintering has especially found a wide application in preparing fines for the blast furnace, and in some cases conducting a roast for the removal of sulphur.—R256: II. SWEETER, *Mining and Metallurgy*, March, 1922, page 13. (F.W.)

DUSTING AND VOLATILIZATION LOSSES DURING MELTING CYANIDE PRECIPITATE AND AIR REFINING OF BULLION.—The authors have investigated these losses on silver and gold precipitate at a

large Mexican mine. In large copper refineries silver losses have been ascertained and recovery established by means of electro static precipitation. With cyanide precipitate accurate information has been lacking. Determining losses by weighing and assaying precipitates has proved uncertain on account of the difficulty in accurate sampling and assaying of this rich material.

Elaborate tests were conducted by the authors to ascertain losses of gold and silver in melting precipitates in small reverberatory furnaces for purposes of final electrolytic refining. Two methods were employed, viz., application of low pressure air nozzled and spread over the surface of the molten metal after the slag had been withdrawn, and forcing high pressure air into the bath of metal itself. Both methods were effective, and resembled expellation practice and copper refining practice respectively.

The determination of volatilization and dust losses were elaborate and included the recovery by filtration and condensation of a measured portion of the fume from the stack. The point of average flow of fume was first located. The losses were found to be small considering that the precipitate was melted in reverberatory furnaces without briquetting. The average loss of silver was 0.1074%, and of gold 0.0280%, for Loreto mine precipitate during melting. The average loss of silver is 0.0625%, and of gold is 0.0150% for the Guerrero mine precipitate during melting. During air refining the average loss for this precipitate of silver was 0.0156%, and of gold 0.0038%. The final bullion (Loreto mine) averaged 973.5 fine in silver, and 5.06 fine in gold. The Guerrero bullion was somewhat lower in silver content.—G. H. CLEVENGER, F. MLOCK and W. HARRIS, *Mining and Metallurgy*, January, 1922, page 11. (P.W.)

MINERAL CONCENTRATION BY ALTERNATE CURRENTS: A PRELIMINARY STUDY OF CERTAIN PHYSICAL EFFECTS.—The author describes certain and most interesting experiments carried out by him on the use of the alternate current for magnetic separation. The work and results described are original and open a new field in this branch of concentration. A number of statements from the paper are quoted hereunder.

"An ordinary laminated alternate current electro magnet behaves more or less like a permanent magnet or a direct current electro magnet when presented to a mass of iron filings or crushed magnetite, tufts of these materials adhering strongly to the poles and joining them by lines of force if they are not too far apart. These effects of alternating magnetism in themselves do not offer any advantage over unidirectional magnetism for the concentration of minerals; on the contrary, they involve a greater expenditure of energy, and at a lower power factor for the production of a given field. But if we carry our experiments a little further we come across certain effects which may be thought of practical and theoretical interest.

"We know specular hematite to be very feebly magnetic; it will not adhere to a permanent magnet, but will do so to a powerful direct current electro magnet. It is so fully magnetic

that it has only been separated from its gangue, with great difficulty, by specially designed powerful magnetic separators. If we plunge the poles of an alternate current electro magnet into a quantity of this material we do not find that any of it adheres to the poles. This excites our suspicion, so we set the magnet, with its poles upward, sprinkle a little of the finely-crushed ore on a glass dish over the magnet, and find that the haematite particles are not attracted, but are actually expelled from the poles in every direction. On tapping the dish gently any gangue that may be present collects gravitationally at the bottom of the dish, and the heavier haematite is expelled up the slopes of the dish away from the poles.

"With some other ores or materials of known feeble magnetic properties we get similar effects."

The author has concluded that the phenomenon described is due to hysteretic repulsion, and is not confined to feebly magnetic materials, but is capable of acting on strongly magnetic materials also under suitable conditions. It also acts on materials immersed in water, even better, because of the decreased force of gravity to overcome due to the flotative effect of the liquid when repulsion of the concentrate takes place. Experiments were conducted on a smaller scale with pulped ore flowing in a launder, and it was possible to repel the mineral to the edge of the launder, the gangue travelling down the middle; and even to repel the concentrate over the sides of a V-shaped launder, the gangue travelling in the centre as if it were of greater gravity. Experiments were also carried out with the separation of wolframite from cassiterite in tin ores; also on lightly roasted chalcopryite ore on which the separated concentrate accounted for 83.7 per cent. of the copper.

The author is of the opinion that only the fringe of the subject has been touched.—W. M. MORDY, *Trans. of South African Institute of Electric Engineers*, December, 1921. (P.W.)

MINING

FIRE PREVENTION AND FIGHTING IN METAL MINES.—There may be some interest in a short list of conclusions of a rather general nature that were reached in connection with some recent mine-fire fighting operations. No effort has been made to cover the field; the items have been jotted down loosely, and very hastily in the order in which they occurred to the writer. Originality is claimed for only a few of them.

(1) Temperature readings and analyses of mine-air samples, systematically taken, are invaluable aids to effective metal mine fire fighting and recovery operations. The analysis of the return-air samples frequently gives a surprisingly accurate indication of conditions existing underground.

(2) Employees must be thoroughly trained in the use of mine rescue apparatus, because a relatively slight difference in the amount of training makes a vast difference in the amount

* Presented at the Mining Section of the National Safety Council, Boston, U.S.A., Meeting, September 27-30, 1921.

of work they can perform under oxygen. In general, slender, wiry men make better apparatus men than those of heavy, more muscular physique, although there are frequent exceptions to any such general statement.

(3) Surprisingly high temperatures, up to 165°F. or 170°F. can be endured for short periods by wearers of mine rescue apparatus if the air is dry, but lower temperatures, 135° to 140° F. are almost unbearable if the air is very moist.

(4) There is likely to be an urgent need of mine rescue equipment and thoroughly trained men familiar with the mine workings at every timbered metal mine.

(5) The choice of fresh-air bases, when performing mine rescue work, is very important, for it must be certain that the air is not contaminated by gases from the fire. If natural ventilation is depended upon, the air current must be watched with care to see that it does not reverse.

(6) The strictest discipline is necessary to prevent men who are returning from the fire zone from removing their apparatus before they reach the fresh air base.

(7) Mechanical ventilation greatly simplifies metal-mine fire fighting operations and increases the safety of the men engaged in the work.

(8) The products of combustion from a fire diffuse with great facility through closely-filled ground for distances that are surprising. This is true even when differences in atmospheric pressure are relatively slight between the burning workings and those that are not affected by flames. Bulkheads in filled ground are absolutely useless, therefore, for fire-fighting purposes, as a general rule.

(9) It is advisable to have bulkheads continuously and frequently patrolled even though they have been recently completed and carefully inspected.

(10) If moist clay can be secured in sacks (or dry clay sacked and moistened) one of the quickest methods of building a satisfactory bulkhead in a drift or cross cut is to put up a wall or brattice of 2in. by 12in. or 2in. by 6in. boards nailed to posts or stulls and fitted as closely as possible at the ends, then to nail two or more 3 by 3, or 4 by 4in. strips on the outside and add another board wall, fastened to the strips, moist clay being tamped between the walls as the outside wall is put up. The outside wall should be calked carefully with clay, especially around the edge and at the top and bottom.

(11) When bulkheading timber drifts or cross cuts, a tight seal rarely, if ever, can be made unless all lagging is cut and a section removed, and all loose rock and dirt taken down before the bulkhead is started.

(12) Close observation of both candle and canary birds is necessary if men working without mine rescue apparatus in the fire zone are to be spared the nausea and excruciating headache of slight CO poisoning. If men working hard are using a bird to warn them of carbon monoxide, the bird should be kept moving enough to make it pant, otherwise it may be affected before the bird shows distress.

(13) The resistance of individuals to low percentages of CO varies between relatively wide limits. Frequently more robust individuals

with large lung capacities are the first to succumb.

(14) Timber fires burn and spread more rapidly than coal fires and conversely die down and cool off more rapidly when the air supply is checked. They are extremely deceptive and likely to blaze up when it is thought that they have been extinguished.

(15) When the fresh-air supply is restricted, an underground fire tends to travel against the air current, even though the current may be coming from below; if the air is moving at higher velocities, so that the supply is more plentiful, the fire may travel both ways. If the draft is extremely strong, the fire will probably travel with it.

(16) Reliable means of signalling from skip or cage should be maintained at all times during fire-fighting operations in shaft mines. The method of signalling becomes extremely important when it is necessary to ride skip or cage in irrespirable atmospheres.

(17) The presence of carbon monoxide in the mine air indicates an active fire (except for the relatively small amounts of CO generated in blasting operations), but the absence of carbon monoxide is not a positive indication that the fire has been extinguished.

(18) Finally, it is pointed out that effective organisation of fire-fighting forces is of paramount importance. Men, equipment and supplies mean nothing, can accomplish nothing, without thorough organisation and the strictest discipline. This is regarded as the most important of all the suggestions and observations.

In connection with the broad problem of metal-mine fire prevention and protection, the following somewhat general observations and suggestions may be of passing interest:—

1. All wooden headframes, wooden structures and supplies of inflammable materials near any mine entrance should be removed or replaced by fireproof structures. If this can not be done, at least such wooden structures should be made as nearly fireproof as possible by means of guniting or some other equally efficient method. All planked floors around the collar of the shaft or at the portal should be removed and non-inflammable construction substituted.

2. Mine timbers should not be piled in the immediate vicinity of the collar of the shaft or at the portal of an adit or a tunnel.

3. Proper storage of dynamite in fireproof places is essential. Boxes of dynamite should not be left near the collar of the shaft or at the portal of an adit or tunnel.

4. Removal of all accumulation of inflammable waste material and refuse from the mine or near the vicinity of the collar of the shaft is important.

5. Proper storage of gasoline or oil at an adequate distance from the mine entrance should receive attention.

6. If underground pump stations or hoist stations need support, steel and concrete, or at least guniting timber should be used.

7. All oily waste should be removed promptly from the vicinity of pump or hoist stations and pending removal should be kept in metal receptacles carefully placed and protected.

8. Electrical apparatus, especially wiring and transformers, should be properly installed and carefully protected. All electrical equipment should be placed in fire-proof stations.

9. The installing of adequate underground and surface fire-fighting equipment, and the organisation of fire-fighting crews are worthy of the most active attention.

10. Fire drills on the surface and underground should be conducted frequently and thoroughly. Those commonly conducted underground are pitifully inadequate and generally come at such long intervals and involve so few men that they are almost worthless. How many men in the average metal mines have an adequate knowledge of the location of escapeways and fire-fighting equipment? How many receive intelligible instruction in these important items with sufficient frequency to retain it with any degree of accuracy?

11. "Second exits" or escapeways are generally intake airways. The best chance that men have when trapped in this way is to bulkhead themselves in dead-ends and wait for rescue. Frequently splitting the air in the ventilating current reduces this danger.

12. Every deep metal mine should be equipped with an efficient means of mechanical ventilation by which the air currents can be reversed quickly, if necessary; and every such mine in which several levels are being worked simultaneously should have its air circulation divided into a number of splits.

13. Some provision should be made to give danger signals or "all out" signals to underground men. Every metal mine should be equipped to introduce a stench into the compressed air lines in cases of emergency, and a supply of the stench-making material should be on hand at all times. Such arrangements are easily made and are not expensive, yet may be the means of saving many lives, especially if all men are well drilled in their use.

14. Crews should be organised for effective down-shift inspections of timbered workings, shaft stations, airways, pump stations, etc.

15. Proper fire doors should be installed at strategic points to assist in the control of the ventilation.

16. The introduction of miners' electric cap lamps and forbidding men to carry matches, flame-making devices, or smoking materials would be an important item in the reduction of underground fire hazards. Of course if fuse is used for blasting the men who split the fuse must be equipped with some type of flame-making device. These suggestions may be regarded as somewhat radical now, but they are feasible, and the time will come when they will receive thoughtful consideration.—H. M. WOLFE, *Mining and Metallurgy*, February, 1922, page 25. (C.I.G.)

UNDERGROUND FIRE PREVENTION BY THE ANACONDA COPPER MINING COMPANY.—During the winter and spring of 1917 an unprecedented number of underground fires occurred in the Butte district. With one exception these fires were caused by the failure of electrical equipment.

Five local conditions that contributed toward a heavy fire risk were: (1) The heavy continuous timbering necessary for mine supports; (2) the strong ventilating pressures in the shafts and main airways; (3) the subsidence and faulting movements in the country rock, which ruptured cables and displaced trolley and lighting wires; (4) the strongly acid

mine waters, which quickly developed any weak points in the electrical insulation; (5) oxidation in old stopes containing large amounts of timber.

In the summer of 1917 a comprehensive plan of fire prevention was begun by the Anaconda Copper Mining Co., comprising fire-proofing, remodelling and strengthening electrical insulations, extension of underground water system, control of ventilation, maintaining efficiency of fire-fighting crews, and the re-organisation of fire patrol.

In considering fire-proofing, some method of applying a durable coat of fire-proof material to the mine timbers was needed. The first experiments were made with a plaster composed of one part cement, one-half part fireclay, and three parts sand, applied by hand over herringbone metal lath. This was too soft and friable for travelling ways, where it was subject to abrasion. The cement gun was tried out with a three to one mixture of sand and cement. A $\frac{1}{2}$ -in. coating of gunite applied over poultry netting or metal-lath reinforcement proved to be durable and fire resisting.

Preparations were made to fireproof the tramway of No. 1 hoisting shaft. This was a four-compartment shaft, 2475 feet in depth; it was lined with framed shaft sets of 12-in. fir timber; the sets were 7ft. by 18ft. 10in. over all, and were spaced 5ft. on centres. The sets were lagged with 2in. pine plank, placed against the rock walls. The timbers and lagging were covered with a half-inch coating of cement, applied with the cement gun over 27-gage diamond-mesh metal lath. The fire-proofing operation was completed in the fall of 1917. Because of the success of this operation it was decided that the twenty-four main hoisting shafts operated by the Anaconda Company in the Butte district, not already so, should be made downcast shafts and similarly fireproofed; also that the same treatment should be given all surface tunnels carrying steam air, and electric power from plant to mines.

Twelve type N-I cement guns were procured and the work pushed as fast as operating conditions would allow. One or more shafts at a time were withdrawn from ore production, re-timbered where necessary, and fireproofed under the direction of the mine foreman. Each foreman selected a crew from among his shift bosses and shaftmen, who were trained at one of the mines where fireproofing work was in progress. The work was carried on continuously by three eight-hour shifts. The crew for each shift consisted of one shift boss, six shaftmen, who miled on the metal-lath reinforcement, two gozzenmen for the cement gun, two runners for the cement gun, station tenders, topmen, etc.

Regarding the details of the gunite work, some general conclusions may be summarised. Poultry netting makes satisfactory reinforcement for covering wooden surface structures of continuous plane surfaces, such as buildings and ore bins; expanded metal lathing is to be preferred where much fitting is necessary, as on underground timbering. A gunite covering half an inch to three quarters of an inch thick on wooden surfaces is sufficient for fireproofing purposes. The sand should be clean and should be screened through a screen four or five meshes to the inch. If the sand is very dry, it does not mix well with the cement, 6 to 10 per

cent. moisture is best. Moisture in excess of 15 per cent. is liable to block the material hose. A mixture of three parts of sand to one of cement is best.

The tramway shaft has had three and a half years' continuous service in ore production since the fireproofing work was completed. A recent inspection of the shaft showed that the timbers from the surface to the 1,600ft. level were 92.5 per cent. covered with gunite; from the 1,600ft. to the 2,800ft. level the timbers were 85 per cent. covered with gunite. The depreciation of the gunite is due to falling rock from overloaded skips—E. M. NORRIS, *Mining and Metallurgy*, February, 1922, page 37. (C.J.G.)

STOPE COST RECORDS AND MINE CONTRACTS OF THE ANACONDA COPPER MINING COMPANY.—Before the present company was formed, in 1916, each group of mines comprising the old organisations made its detailed daily and monthly mine cost records along the lines used before the consolidation; that is, there was no attempt made to standardise and compare the stope costs of all mines. The general cost sheets for all mines, however, were standardised, and cumulative labour cost sheets were compiled in the general superintendent's office.

Probably 95 per cent. of the stopes were square-set worked by day's pay; there were some back-filling and shrinkage stopes. Many of the development places, such as shaft sinking, station cutting, drifting and raises had always been run by contract. These contracts were given, for no definite period, at so much per linear foot and were measured monthly, or when completed, the men being paid monthly. In some cases, fairness to the employee was not maintained. On the whole, there was no standardisation. There were no stope contracts because of the objections of the Western Federation of Miners to general contracting in the mines.

Early in 1916 W. B. Daly, then General Superintendent, and the author, then Assistant General Superintendent, visited the south-west mining districts with the object of finding some improved method. On account of local conditions on the surface, as well as underground, the fact was kept in mind that no new method would be acceptable that would cause:—

(1) A settling of the surface or any underground workings or shafts then in use, or that would be used in the future.

(2) A lowering of the grade of the ore.

(3) A violation of the rules of the Safety First Department.

The result of this trip was the adoption of the following methods:—

(1) The cut and fill, or rill system, in all veins where the ore and walls are fairly hard, whether the ore must be sorted or not.

(2) The timbered rill, where the ore and walls are not hard, whether the ore must be sorted or not.

(3) The use of chutes every fifth set in square-set stopes and the more general use of slides to chutes.

(4) The keeping of daily cumulative detailed costs for each stope that the foreman may check the efficiency of his men.

(5) The employment at each mine of men having a thorough knowledge of underground

mining and accounting to maintain a system of detailed costs.

In connection with these new methods, it was our desire to provide for obtaining, recording and using the following information:—

(1) The comparative efficiency of different stoping methods.

(2) The comparative cost of labour by different stoping methods.

(3) The comparative cost of supplies by different stoping methods.

(4) Total saving by new methods over o.d.

(5) Efficiency, labour and supply costs of each stope in each mine and the separate details of these costs.

(6) Periodical cumulative costs of all stopes.

(7) A record of all mines stope costs for each foreman and superintendent.

Each mine, at the end of the month, has a completed stope cost record which is sent to the office of the General Superintendent, where the general stope cost record for all mines is made up. This sheet is almost a duplication of the mine stope cost record. It is made on tracing cloth, blue printed, and sent to each foreman and assistant Superintendent. Powder, caps and fuse are combined under explosives and net savings of the other methods over square-set stoping are shown. This system, and the methods of obtaining the information, have been used five years and have required no changes.

The custom of contracting on sills in shafts, raises and stations still is carried on; repair work, stoping, tramping and all other work had always been by day's pay. Stope contracting, though was not practised until April, 1919. This system was gradually installed until, by July 1st, 1919, it was an actual working success in all stopes at all mines. Work in all stopes, raises, drifts, crosscuts, shafts and winzes is now done by contract on a cubic foot basis, the price per cubic foot being regulated according to conditions, such as the hardness of the ore or waste, the width of the ore, the method of stoping, accessibility, temperature and humidity.

The contracts are made for one week, at a set price but may be terminated after one day by either the foreman or the contractors. The men are notified of the price on Thursday morning, which is the beginning of each contract week. No change in the rate per foot is permitted during the life of the contract, but adjustments are made in special cases, which must be noted by both the engineer and the foreman. The general benefits derived are:—

1. The cost per ton of ore is less by contract. The men who are willing to work are given some individuality and the conservative men are inclined to break away from the I.W.W. theory of doing as little as possible in order to get by.

(2) The stope cost record and contract system have given a more accurate check on the cost of underground operations than any method we have used.

(3) By subtracting the ore tally from the engineers' contract measurements, a direct check on waste broken or tons of rock broken to obtain a ton of ore in each stope is obtained.

(4) Measurement is allowed between the walls only, except where the wall is removed for timber. It is, therefore, to the best interests of the men not to break the walls, and the ore is kept cleaner and the average grade increased.

(5) By taking the difference between the total labour cost of a stope on the stope cost record and the total contract money, the direct percentage of contracting in each stope or at each mine is obtained. Over 90 per cent. of the stope shifts are contract shifts. Any comparative cost data desired may be obtained directly from these records.

(6) The contract system tends to keep the foremen and all bosses in closer touch with the men and creates better supervision. When contracts are given the list is posted at the mine showing price per foot and, when finished, full information of the results is posted, showing: contract number, working place, price per foot, total shifts, total money, and rate earned. Every man at the mine is paid weekly, which accounts for a great part of the successful operation of contracts.

It is understood at all mines that any contractor is free to interview the foreman of the mine and, if a satisfactory adjustment of his complaint is not made, he may take his case to the company labour commissioner. The case is then brought to the General Superintendent. During the period of general contracting from April, 1919, to date, over 60,000 contracts have been let, but only six have been brought to the General Superintendent for adjustment. This record is sufficient evidence that the method is a proper one, and can only be attained by the most careful superintendence and absolute fairness to the employees.—C. L. BERRIEN, *Mining and Metallurgy*, February, 1922, pp. 54 and 55 (C.J.G.).

SHAFT SINKING BY CAISSON.—An interesting account of shaft sinking methods at an American colliery is given in *Coal Age* by Alphonse F. Brosky. Soon after the decision had been reached to construct the Logan Ferry Mine with the central power station of the West Penn. Power Company, across the Allegheny River at Springdale, active construction began. In the summer of 1920 work was started on the sinking of the hoisting shaft at a point a little north of the central station. The usual method of excavating shafts was adopted, but it was found necessary to change these methods in consequence of the large quantities of water to be handled. The elevation of the surface at the shaft site is 744 feet above sea level, and the existing water line and pool height are 736 feet and 733 feet respectively. It was believed that the best course to pursue in sinking through the loose material would be to drive sheet piles around the excavation. Little trouble was experienced in sinking the shaft by this method until a depth of 35 feet below the surface had been reached, but below this level the pumps were entirely unable to cope with the rapid inflow of water. Furthermore, the driving of piles had become difficult, for their cutting edges began at this level to strike boulders. To overcome the difficulty at hand the pneumatic or caisson method was resorted to, the work being carried on by the Foundation Company. As the shaft had been sunk to a depth of 23 feet by the piling method

the caisson plan had to be modified to meet the conditions encountered. The first step was to refill five feet of the excavation so as to raise the bottom from the point where pumping was found inadequate to an elevation at which all the water entering could be voided. The pump installation was kept intact, temporarily. The cutting edge of the caisson was placed at the level attained by backfilling, and oval walls were built up, the pile braces were removed and the intervening space filled. Upon passing the ground level with the lining wall construction the caisson method proper was followed, this procedure being maintained until bedrock was reached. In this work the Moran type of air lock was employed under an average air pressure of 23lb. The lining was sunk through 10ft. of seamy rock to a solid footing. Here it was sealed to the solid with concrete, which was kept under air pressure for a period of three days, after which the air lock, shafting and deck were removed. The water was completely sealed from the shaft as far as bedrock. The rest of the shaft below this point was then completed by the owners, its total depth being 162 feet. No pipes or other obstructions of any kind are to be found in this compartment, and a safe travelling way for men is thus provided against the time of need.—ALPHONSE F. BROSKY, *The Colliery Guardian*, originally in *Coal Age*, January 27, 1922, page 217, (J.C.).

CORRECTION. The Preservative Treatment of Mine Timber, Page 175, the tenth paragraph should read "Copper sulphate is suitable underground, but not where waters are rich in iron."

MISCELLANEOUS

PLANT OF THE MOZAMBIQUE PORTLAND CEMENT CO., LTD., AT LORENÇO MARQUES.—The Portland cement factory of the Mozambique Cement Co. will have an output of 700 tons of Portland cement per week.

The method of manufacture is upon the wet process. The raw materials are brought to the factory by barge, where they will be unloaded upon a jetty and transferred to the factory.

The limestone is fed to jaw crushers, 1,000 mm. by 500 mm., after which it passes through crushing rolls. This reduces the limestone to approximately walnut size. It is then elevated into a hopper over a compound ball and tube mill 11 metres long and 1.8 metres in diameter. The clay, when delivered to the factory, is first dealt with in a wash-mill, after which it is pumped into the compound ball and tube mill and ground with the limestone. Water is introduced into the grinding mill, and the limestone and clay are ground together in the wet state (about 40 per cent. of water) to a fineness of about 10 per cent. on 180 mesh sieve.

The "slurry" as it is termed, coming from the compound ball and tube mill is elevated into one of three mixers, where it is thoroughly mixed and proportioned. One mixer is of sufficient capacity to enable the kiln to run over the week-end without refilling. The slurry transport and agitation is carried out in a special manner. Hitherto slurry has been pumped by plunger or centrifugal pumps and agitated mechanically. In this factory, however, completely new methods are introduced,

and the slurry is elevated by means of pressors and is agitated in the tank by means of blasts of compressed air. When found to be of correct proportions for calcining, the mixing tank is sealed and is used for the supply of the kiln. It is pumped into a small tank over the feed end of the rotary kiln and gravitates into the kiln. The kiln itself is 56 metres long and 2,800 to 2,300 mm. in diameter. The plates in the firing zone are approximately $\frac{7}{8}$ in. in thickness, and the kiln is furnished with four cast-steel rollers and a cast-iron rim for the drive. The cooler is attached to the kiln in prolongation. This attachment permits of several advantages, notably, only one motor to drive, instead of two where the cooler is separate; much lower foundations; absence of stairs, gangways, etc., and perfect accessibility and easy attendance. Furthermore, no movable kiln head is required; and a considerable saving through the utilisation of heat radiated from the material passing through the cooling section is effected.

Coal is supplied to the kiln in the following manner: When delivered to the factory, by trucks run in on the company's siding, the coal is first crushed and thoroughly dried in a rotary drier. It is then passed through a small compound ball and tube mill, 8 metres in length and 1.4 metres in diameter. It is then elevated into a storage hopper, from which it is wormed into the coal feed pipe through which a continuous blast of air passes by means of a high-pressure fan. The clinker coming from the cooler is taken on a shaker conveyor to the boat of an elevator, which elevates on to another conveyor running over the

and elevated into the cement store, where automatic sack-packing machines have been provided.—*South African Engineering*, February, 1922, page 27. (A.K.)

DECIMALISING STANDARD MEASURES.—Although our present systems of weights and measures and monetary divisions have certain disadvantages compared with the decimal system, a compromise may be reached with the aid of simple tables, which enable shillings and pence to be converted instantly into decimals of a pound sterling, and cwt.s, qrs. and lbs. as easily and quickly into decimals of a ton. Once having resolved these complicated proportions into decimals of the largest unit, many of the advantages of the metric system can be enjoyed.

A brief inspection of Table I. shows its simplicity; it is as easy to read as an ordinary table of logarithms, and after very little practice any intelligent storekeeper will be able to use it with facility. The shillings column, marked S., is on the extreme left, and is read vertically from 0 to 20. The pence column runs horizontally along the top, and reads from 0 to 11. The other figures are the decimals of £1 corresponding to any number of shillings and pence. To express any sum given in shillings and pence, as a decimal of £1, it is only necessary to look down the S. column for the number of shillings, and then follow the horizontal line to the required number of pence in the pence column. Thus to express 13s. 6d. as the decimal of £1, find 13 in the shillings column, follow the horizontal line as far as 6 in the pence column, and read off 0.6750, the

TABLE I.—Pence

S.	0	1	2	3	4	5	6	7	8	9	10	11
0	0.00	0.0042	0.0083	0.0125	0.0166	0.0208	0.0250	0.0292	0.0333	0.0375	0.0417	0.0458
1	0.05	0.0542	0.0583	0.0625	0.0666	0.0708	0.0750	0.0792	0.0833	0.0875	0.0917	0.0958
2	0.10	0.1042	0.1083	0.1125	0.1166	0.1208	0.1250	0.1292	0.1333	0.1375	0.1417	0.1458
3	0.15	0.1542	0.1583	0.1625	0.1666	0.1708	0.1750	0.1792	0.1833	0.1875	0.1917	0.1958
4	0.20	0.2042	0.2083	0.2125	0.2166	0.2208	0.2250	0.2292	0.2333	0.2375	0.2417	0.2458
5	0.25	0.2542	0.2583	0.2625	0.2666	0.2708	0.2750	0.2792	0.2833	0.2875	0.2917	0.2958
6	0.30	0.3042	0.3083	0.3125	0.3166	0.3208	0.3250	0.3292	0.3333	0.3375	0.3417	0.3458
7	0.35	0.3542	0.3583	0.3625	0.3666	0.3708	0.3750	0.3792	0.3833	0.3875	0.3917	0.3958
8	0.40	0.4042	0.4083	0.4125	0.4166	0.4208	0.4250	0.4292	0.4333	0.4375	0.4417	0.4458
9	0.45	0.4542	0.4583	0.4625	0.4666	0.4708	0.4750	0.4792	0.4833	0.4875	0.4917	0.4958
10	0.50	0.5042	0.5083	0.5125	0.5166	0.5208	0.5250	0.5292	0.5333	0.5375	0.5417	0.5458
11	0.55	0.5542	0.5583	0.5625	0.5666	0.5708	0.5750	0.5792	0.5833	0.5875	0.5917	0.5958
12	0.60	0.6042	0.6083	0.6125	0.6166	0.6208	0.6250	0.6292	0.6333	0.6375	0.6417	0.6458
13	0.65	0.6542	0.6583	0.6625	0.6666	0.6708	0.6750	0.6792	0.6833	0.6875	0.6917	0.6958
14	0.70	0.7042	0.7083	0.7125	0.7166	0.7208	0.7250	0.7292	0.7333	0.7375	0.7417	0.7458
15	0.75	0.7542	0.7583	0.7625	0.7666	0.7708	0.7750	0.7792	0.7833	0.7875	0.7917	0.7958
16	0.80	0.8042	0.8083	0.8125	0.8166	0.8208	0.8250	0.8292	0.8333	0.8375	0.8417	0.8458
17	0.85	0.8542	0.8583	0.8625	0.8666	0.8708	0.8750	0.8792	0.8833	0.8875	0.8917	0.8958
18	0.90	0.9042	0.9083	0.9125	0.9166	0.9208	0.9250	0.9292	0.9333	0.9375	0.9417	0.9458
19	0.95	0.9542	0.9583	0.9625	0.9666	0.9708	0.9750	0.9792	0.9833	0.9875	0.9917	0.9958
20	1.0											

whole length of the clinker store. Sufficient storage has been allowed for four weeks' output at the rate of 1,400 tons per week (the factory is so designed as to permit of duplication in the near future). The clinker is reclaimed by a conveyor running underneath the clinker store house, and after the gypsum has been added is elevated over a compound ball and tube mill for clinker grinding. The cement is ground to a fineness of 8-10 per cent. on 180-mesh sieve, and is wormed

required decimal. Again, 17s. 9d. will be found to be 0.8875; that is, along the line 17 in the shillings column and under 9 in the pence line the figure 0.8875 will be found. The pounds are, of course, untouched, so that a sum of £52 11s. 8d. will appear as £52.5833, a figure easily dealt with by the slide-rule; or, if extreme accuracy is required, a table of five-figure logarithms.—H. WILLIAMSON, *The Iron and Coal Trades Review*, February 24, 1922, page 275. (J.A.W.)

205

THE JOURNAL

OF THE

Chemical, Metallurgical and Mining Society

OF SOUTH AFRICA

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Vol. XXII.

MAY, 1922.

No. 11.

Proceedings AT Ordinary General Meeting, 20th May, 1922.

The Ordinary General Meeting of the Society was held in the Assembly Hall, Scientific and Technical Club, 100, Fox Street, Johannesburg, on Saturday, the 20th May, 1922, at 8 p.m., Mr. F. Wartenweiler (President) in the chair. There were also present:—

28 Members: Messrs. C. J. Gray, Prof. G. A. Watermeyer, F. W. Watson, H. R. Adam, J. Chilton, A. King, Dr. A. J. Orenstein, J. E. Thomas, John Watson, H. A. White, J. A. Woodburn (Member of Council), H. D. Bell, Dr. W. A. Caldecott, R. A. Cooper, G. Cottrell, J. M. Dixon, J. Henderson, E. Homersham, H. Rose Martin, C. A. Meiklejohn, Lieut.-Colonel E. Pam, F. N. Phillips, T. Proberts, J. J. R. Smythe, J. Symons, J. M. Thorburn, J. T. Triggs, and 11. R. S. Wilkes.

4 Associates: Messrs. O. A. Gerber, G. B. Gordon, H. Ruden and W. Russell.

6 Visitors and H. A. G. Jeffreys (Secretary).

MINUTES.

The President said that, owing to the April meeting having been delayed for one week on account of the Easter Holidays, it had not been possible to have the *Journal* published in time for confirmation of the Minutes of the April meeting. Therefore it was necessary to postpone their confirmation until the next meeting.

NOMINATION FOR OFFICERS.

Members were reminded that nominations for Officers of the Society for the ensuing year should be sent in to the Secretary before the 24th of the month.

SCRUTINEERS FOR ANNUAL BALLOT.

Messrs. S. Newton, A. Thomas, P. T. Morrisby and J. M. Dixon were nominated and elected scrutineers for the annual ballot for Officers of the Society in June.

NEW MEMBERS.

A ballot was taken for the election of new members, and the following were declared unanimously elected:—

HARDING, E. G., Government Gold Mining Areas (Modderfontein) Cons., Ltd., Brakpan: Surveyor.

HYND, JOHN, P.O. Box 4, Bulawayo: Consulting Mechanical Engineer.

TAVENER, P. S., P.O. Koosfontein, near Bloemhof: Metallurgist.

The Secretary announced that the following gentlemen had been admitted by the Council as Associates:—

GILBERTSON, STUART K., Village Deep, Ltd., Johannesburg: Reduction Worker.

LETHBRIDGE, F. W., Village Deep Ltd., Johannesburg: Reduction Worker.

MORGAN, A. S., Blinman's Buildings, Eloff Street, Johannesburg: Dental Surgeon.

WEIL, JULIUS, c/o Messrs. Lewis & Marks, Johannesburg: Director of Companies.

EXHIBITION AND DEMONSTRATION OF DEVICES OF PRACTICAL ADVANTAGE.

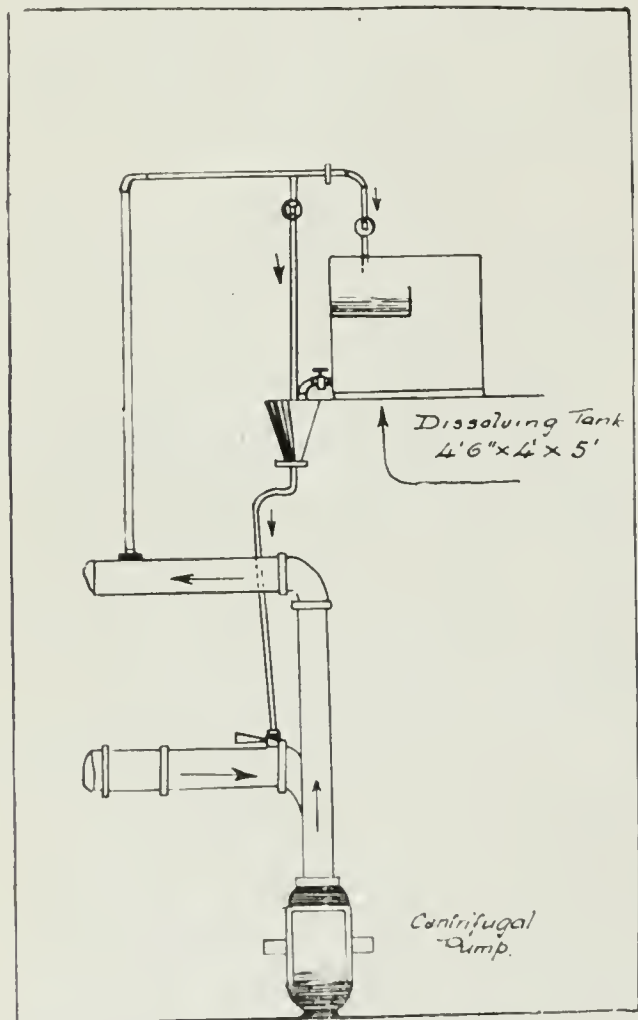
APPARATUS AND METHOD FOR STANDARDIZING WORKS CYANIDE SOLUTION.

Mr. W. D. Dodds: The accompanying sketch shows the method used at the City Deep in standardizing their works cyanide solution.

The dissolving box is filled up to the height of solution required from branch connection from delivery pipe and an amount of cyanide equal to 6lbs. per inch of solution is put on the screen and dissolved. Any

suitable poundage can of course be added, but it is preferable to keep to a constant to avoid errors.

When starting to pump on to sand tanks, in order to keep the pipe from the funnel full and avoid losing the suction, the branch connection from the pump delivery is opened to the funnel in conjunction with the regulated feed from the standardizing tank. It is quite a simple matter for shiftmen when they know the volume of solution pumped per minute, to regulate the make-up feed.



A series of tests are taken from time to time at the pump delivery of the solution going on the sand tanks, and the variation in strength has been found negligible, being not more than .005 at any time during the period of saturating a sand charge.

The suction and deliveries of the pumps are arranged so that this method of standardizing can be used for either sand or slime treatment.

I think the arrangement is a distinct advantage over the method used on many mines of making up large volumes of solution in a sump, as hydrolysis due to circulation and agitation of considerable quantities of strong solution are avoided.

The President thought it was an opportune time to bring this subject again before the members of the Society, in view of the fact that dissolving tanks for cyanide might assume greater importance in the future. He referred to experiments which were about to take place on one of the mines in the use of a low-grade cyanide in which there was a considerable amount of inert matter.

They had with them that evening Mr. Buch, who, as a technician, had experience in the manufacture of cyanide. Perhaps Mr. Buch would like to give them some idea as to how low-grade cyanide was manufactured. It gave him great pleasure to introduce to them Mr. Buch.

Mr. N. W. Buch expressed his pleasure at having the opportunity of attending the gathering of the Society and meeting the members present. He believed a brief description of the new cyanide and the method used in manufacturing would probably be of interest to the members, as it has not been used heretofore on the Rand.

Standard text-books gave the reactions involved in the manufacturing process, but the complete commercial development of the process was not accomplished until early in 1919. Attempts to manufacture this type of cyanide had been made during the past twenty years without success. The manufacture was undertaken during the war for purpose of supplying cyanide owing to a shortage of this material existing in America. A low-grade cyanide was manufactured which was used with satisfactory results. The greater part of the requirement of the mining and citrus industries of America was to-day being supplied in the form of cyanimid cyanide. Recently the case hardening and the electroplating industries had also taken up the use of this material in specially prepared form.

The cyanide under discussion was manufactured from cyanamid, which was a nitrogenous fertiliser used as a substitute for nitrate of soda and sulphate of ammonia.

Cyanamid was manufactured by first fusing coke and lime in electric furnaces of approximately 15,000 h.p., the product being calcium carbide. This was pulverised to about 100 mesh, using tube mills, grinding being done in an atmosphere of nitrogen. The finely divided carbide was then placed in electric furnaces of special design, and nitrogen passed through the finely divided

charge. The reaction was exothermic after once started.

The calcium cyanamid was then fused with salt in another type of electric furnace the resulting product being the cyanide under discussion.

The cyanide as tapped from the furnace must be chilled quickly, otherwise reversion takes place to cyanamid and carbon. This reversible action was very interesting and unusual.

The material was of a black, shiny appearance in the form of thin scales, varying from 1-16th to 1-32nd of an inch in thickness, and from $\frac{1}{4}$ in. to $\frac{1}{2}$ in. in area.

The approximate composition is as follows:—

Sodium cyanide (equiv.)	49.90%
Cyanogen... ..	26.66%
Calcium	33.15%
Sodium	15.30%
Chlorine	17.50%

It was of interest to note that at least part of the cyanogen was present in the form of calcium cyanide.

The results as to extraction, precipitation and cyanide consumption had shown no differences from the grades of cyanide used heretofore in the treatment of gold and silver bearing ores.

Owing to the content of unhydrated lime it was preferable to dissolve the new cyanide in a solution tank to prevent localised heating of the mass which causes decomposition of the cyanide present. It was advisable to have some method of agitation during solution.

He hoped that this brief description of the product and method of manufacture in Canada of this new cyanide would be found interesting and informative.

Mr. H. A. White said he would like to remark that the furnace used for transforming calcium cyanamid into calcium cyanide must be of a somewhat peculiar type, because a lot of experiments were made in this country during the war in the attempt to perform that same operation. They were made on a fairly small scale. He believed Dr. Caldecott could tell them he had made some on a fairly large scale—up to 100 pounds, but the difficulty was that they could not get the cyanide up to anything like 50 per cent., probably the difficulty of cooling it sufficiently rapidly in large pieces was responsible.

Another difficulty was that the action of moisture upon the slowly cooling product was one which rapidly caused it to be converted into ammonia. Evidently those two little difficulties must have been got over.

A DEVICE FOR TESTING THE PERMEABILITY OF SLIME.

Read at April Meeting.

Mr. B. L. Gardiner: Having had occasion recently to make use of a simple device for testing the permeability of slime from the vacuum filtration point of view, it occurred to me that a short description might be found useful to others.

It is not claimed that the device is particularly new or of great accuracy when applied, but it is essentially simple, and can be put together in ten minutes, and might be of especial service on out-of-the-way mines not provided with much in the way of testing laboratory apparatus. Such an instance recently took place when the writer was visiting a mine in Rhodesia and desired to know whether the slime there was suitable for vacuum filtration or not, and inside an hour the very useful affirmative information was in his possession.

The following is a brief description:—

Required: A length of glass tube about half an inch internal diameter and about 5 ft long (a 100 cc. burette will do if the glass tube is wanting); two medicine bottle corks; a nail; a piece of string; a small piece of cloth.

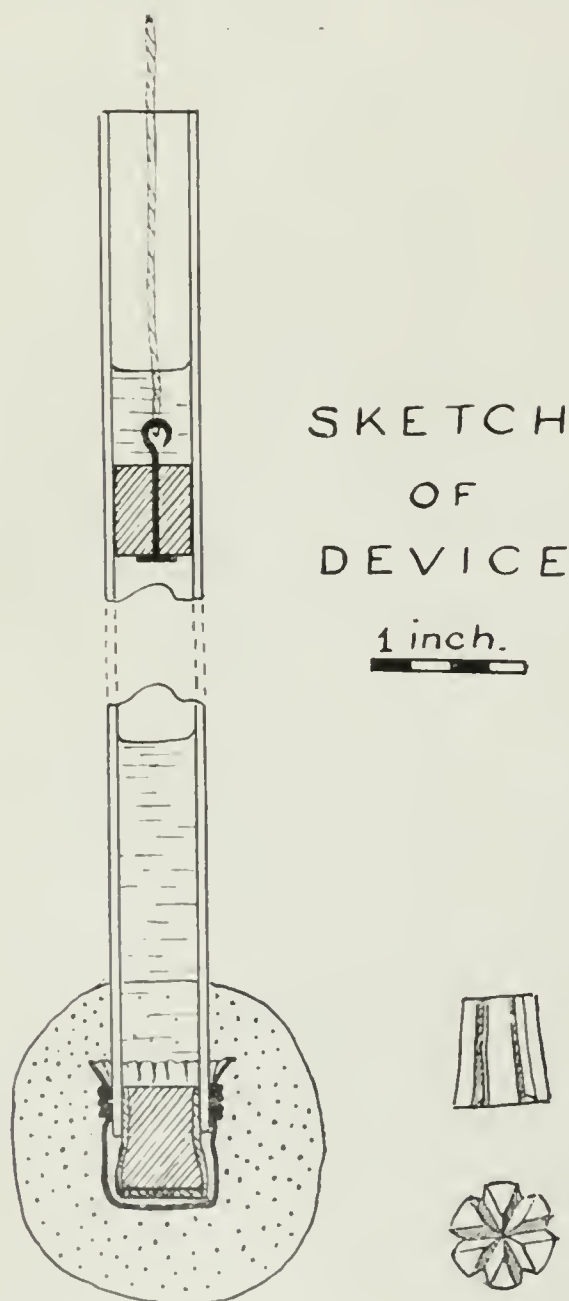
One cork is made to fit in the end of the tube just as it fits in the medicine bottle, but it is nicked with a knife, as here shown, before fixing. A piece of cloth, calico, or such like, is then drawn over this cork and the end of the tube, and bound to the tube with a piece of string. The other cork must be a neat fit inside the tube, so that it can slide up and down as a piston. The small nail is pushed neatly through the centre of this cork and the end bent over to make a hook.

The apparatus is now ready for work.

Operating. Pour a little water down the open end of the tube to lubricate, and then push in the piston cork attach a length of string to the hook, and with a thin rod push the piston down the tube so as to just touch

the other cork already inserted there. Pour about one inch of water on the piston to form a seal.

Holding tube vertically, submerge the lower end into a vessel containing the slime pulp, and then draw up the cork piston by means of the string, thus creating the vacuum. It will be found that the cork piston, if sufficiently firm a fit, will stay up, and there is no need to anchor it by fastening the string. If a clamp is available the



tube may be fixed in an upright position and the operation watched.

It will be noted that the filtered solution immediately begins to rise in the tube, and through the column of solution rise numerous small bubbles, which are the dissolved gases being driven off from the solution in

vacuo. The liberated gases, of course, tend to reduce the vacuum, and it might be expected, would vitiate results in so far as a useful comparison is concerned with the uniform vacuum such as is usually maintained in practical work. My results show that the amount of gases given off is not an important factor provided the tube is fairly long, and even with a short tube (3 feet) the solution has risen steadily till not less than 9-10ths of the vacuum space was filled.

The progress of the filtration can be watched very closely by noting the rate of rise in the solution level, and by measuring the increase at definite time intervals, an interesting curve can be plotted which helps to determine the economic time to which the filtration should be carried.

After sufficient time of filtration has been allowed, the arrangement is removed from the pulp, and a ball of thick slime, corresponding to the "cake" in filters will be found adhering to the end of the tube; the thickness of this can be determined by prodding radially with a clean splinter of wood, or allowing to dry out partially under the influence of the vacuum, and then making a careful section. Given the thickness of cake in the given time it is a simple matter to calculate the capacity of a vacuum filter.

If the slime pulp has been agitated sufficiently with cyanide solution before commencing a test, the rod with ball of slime attached can be transferred to a vessel containing wash water and the operation of washing continued, giving useful information in regard to the rate the wash comes through, and finally by removing, drying and assaying a good indication of the residue that may be expected by vacuum filtration methods.

The device, being quickly and easily arranged, is also useful in making comparative tests on the influence of substances such as coagulants on the filtering rate, or in determining the effect of any other factors of a similar nature.

It has been suggested that an arrangement on some such lines might be devised for determining quickly whether the de-aeration of cyanide solution, as practised in some places, is being carried out satisfactorily—the absence or presence of bubbles in the column being a sort of rough indicator of the degree of de-aeration.

NOTES ON OSMIRIDIUM.

By J. R. THURLOW.

In view of the interest which is being taken in osmiridium, to judge by the frequent references appearing in the local press, no apology is needed for placing before the members of this Society a brief record of what has been done locally hitherto, and more particularly the results which have been obtained during more recent research on this valuable constituent of banket ore.

The first serious attempt at commercial realization known to the writer was made by the late Mr. M. Torrente during the period 1912-1913, when he succeeded in isolating and fusing into metallic form a small quantity of the metal iridium. Mr. Torrente carried out a considerable amount of research work on concentrated black sand, resulting from milling operations from one of the mines in the Central Rand, and, with a view to establishing commercial relationships, was in correspondence with well-known firms in England and on the Continent for some considerable time.

The next and more successful attempt of this kind occurred during the latter part of 1920 on a mine situate in the Eastern Rand section. It may be noted, however, that periodically during the intervening period more or less frequent references were made to the fact of the presence of rare metals other than gold in concentrated products resulting from metallurgical operations. In the main, however, these references were concerned mostly with analytical work, quite frequently it was a subject for argument in connection with the assaying of concentrates dealt with by the Co-operative Smelting Works.

The nearest approach to its successful isolation from the commercial aspect, viewed in light of present day knowledge, would appear to be when a small quantity, containing 20% osmiridium and 3% platinum, was passed round for inspection at a meeting of this Society, held in October, 1915,* when Messrs. W. H. June and F. Davey presented a paper on Clean-up room practice.

The history of the 1920 incident is worth recording as an instance of the benefit resulting from scientific training and its natural outcome in the shape of an intelligent interest in whatever work is being

undertaken. The curiosity of an assayer led to a discussion as to the nature of a certain blue-black material which he had observed to form a ring round the outer edge of the material passing through a batea. As a sequel a small portion was collected which, on analysis, proved to contain a high percentage of osmiridium. Subsequent investigation indicated that a natural concentration of this product was occurring in the clean-up room, and advantage was taken of its incidence to evolve an economical process of recovery.

After a good deal of experimental work in the direction of hydraulic concentration the simple system described herein was adopted, and meanwhile gradual improvements are taking place which lead to increased efficiency.

In connection with the experimental work it may be mentioned that a magnetic process was tested, and while it was found that osmiridium was attracted with the magnetic metallic iron to the various poles, probably due to the magnetic film covering, no real concentration was effected.

A description of the method referred to above as employed on reduction plants of the Rand Mines Central Mining Group is as follows:—

Proceed in the usual manner to grind in the clean-up barrel all black sands collected from the amalgamation plates and the products from the traps, mortar box heads, Willley tables, etc. Pass the ground material through the batea also as usual, but take precaution to keep the final heavy concentrates remaining on the batea separate from the lighter portion which flows over the trap plate. By this means a product containing 40% of osmiridium concentrate has been obtained, and where this is possible the simplest method of further treatment is to pan off the base metals in a prospector's dish. The most satisfactory method at present of dealing with the product from the collecting sump of the batea is to pass it over a small table, which is covered with open grained calico resting on fine mesh (100) screen.

The dimensions of this table may be made to suit the working space available; the tables at present in use are about 5 feet long by 2 feet wide, and are made with a

*See *Journal October, 1915, Page 67 et sequentes.*

small head box and distributing lip similar to those situated at the heads of the tube mill plates. The inclination of the table depends upon the material being concentrated, and the operator can soon decide what this should be to obtain the best result. A grade of 20% is found to work very well, but as the table is usually a portable one and only set up as required, it can readily be adjusted to suit working conditions. The concentrate caught on the table is further dressed by panning, and the product of this operation is treated by acid. It may be pointed out that as all operations prior to concentration on the calico-covered table are contributory to the ordinary routine, the operating charges per ton of ore treated are practically unaffected.

The following table gives typical analyses of the results obtained by the above means after the product had been subjected to treatment with weak acids:—

	1	2	3	4
	%	%	%	%
Iridium ...	43.9	44.51	37.86	33.25
Osmium ...)	41.9	25.38	34.75	37.79
Ruthenium .)		10.50	10.04	10.47
Platinum ..	3.0	7.04	6.37	5.80
Rhodium ...	1.3	0.53	0.82	0.70
Gold	3.0	3.09	3.60	2.86
	<u>93.1</u>	<u>91.05</u>	<u>93.44</u>	<u>90.87</u>

Analyses by R. A. Cooper, Rand Mines, Ltd., Laboratory.

The following copy of a complete analysis of "Black Sand" was given to the writer by the late Mr. M. Torrente:—

	%
Iron	35.32
Sulphur	41.27
Copper ... ..	.05
Lead ... ..	.03
Nickel ... ..	.20
Cobalt ... ..	.24
Zinc ... ..	.48
Arsenic ... ..	.33
Silica	19.65
Alumina ... ..	.50
Chromium Oxide ... ..	.08
Lime ... ..	.17
Magnesia ... ..	.12
Titanium Oxide ... ..	.95
Oxygen, Combined and Hydroscopic	
Water, Gold and Metals of Platinum Group ... ..	.61
	<u>100.00</u>

Fine Gold ...	1.33 ozs. per ton of 2,240lbs.
Fine Silver .	2.00 ozs. per ton of 2,240lbs.
Platinum ...	.43 ozs. per ton of 2,240lbs.
Iridium... ..	3.00 ozs. per ton of 2,240lbs.
Palladium ...	.45 ozs. per ton of 2,240lbs.

On sample as received.

As regards the amount of osmiridium present in the ore milled, tests have shown that it varies from 1 ounce per 5,000 tons to 1 ounce per 15,000 tons.

Taking the mean of these extremes, to arrive at a monthly output of 100 ounces osmiridium 1,000,000 tons would have to be milled. The computation is made on tests carried out on mines situated on the Far East Rand. So far only negligible quantities have been isolated on mines west of the Modder Group.

COMMERCIAL VALUE.—The most valuable constituent of the concentrate is iridium, which, however, is subject to violent fluctuations in price according to demand. Thus it realised £120 per ounce two years ago as compared with one-fifth of this amount per ounce more recently.

COMMERCIAL USES.—The chief uses of osmiridium or the metals contained therein have hitherto been:—

- (1) Fountain pen points.
- (2) Contacts used in magneto points of the highest class of motor cars.
- (3) Irido-platinum alloy used in thermocouples.
- (4) Hardening parts of certain dental instruments.
- (5) Watch and compass bearings.

Mr. H. A. White thought the Society was to be congratulated upon receiving these notes, which would no doubt be very valuable to those who were considering the question of attempting the recovery of this material, the value of which, of course, depended to a very large extent upon the supply. So that, if all the mines were to set to work and turn out some hundreds of ounces of iridium per month the price would unquestionably soon go down below that of gold. They had not an accurate idea of the percentage of extraction of the osmiridium present in the ore. The figures they had heard read out to them that evening were merely based upon recovery results: one ounce had been extracted from 15,000 tons, or 5,000 tons, as the case might be. He had made a few experiments on that point, but they were not sufficiently

adequate to enable him to give those present any definite information as to the results arising therefrom; but he had a strong sus-

picion that the recovery was not more than 40 per cent. to 50 per cent. of the actual osmiridium present in the ore.

TECHNICAL EXAMINATION OF LUBRICATING OIL AND GREASE.

By F. W. WATSON, B.Sc., F.I.C., and H. D. BELL.

Comparatively little has been published in South Africa on this very important subject, in fact the authors have been unable to find any contribution thereon in this Society's Journal.

In the present paper we propose to deal with the subject from the point of view of the chemist, therefore the paper will consist mainly of analytical methods and data.

It has been found that engineers who had obtained satisfaction from a lubricant for one particular purpose were inclined to use the same article for an entirely different class of work, and, naturally, satisfactory results were not obtained.

Analyses and physical tests, conducted on some of the lubricants on the market, have shown that many were entirely unsuitable for the purpose proposed. Many oils and greases which have favoured trade names are sold at higher prices than equally good or better articles, in many cases the chief or only qualification for the high price is the name.

As might be expected there is considerable variation in the opinions held by competent judges as to what is the desired standard for any particular type of lubricant. Thus some authorities consider that a cylinder oil should contain no animal or vegetable oil, others hold that a small percentage of these is of distinct advantage, while others again consider that a small percentage of free fatty acid is an improvement.*

We have found that materials which approximately come within the specifications shown in the accompanying tables, have given great satisfaction in practical use and publication of these details may therefore prove useful to others and indicate what are the requirements for the various types of oil and grease.

The subject naturally divides itself into two distinct parts—oils and grease—and we propose first to consider the former.

The tests which have been carried out on oil samples are as follows:—

- (a) Flash point—closed test in Pensky Marten apparatus.
- (b) Viscosity at temperature specified, being the time in seconds which elapse during the efflux of 50 cc. in the Boverton Redwood viscometer.
- (c) Specific gravity at 60° F.
- (d) Free fatty or mineral acid.
- (e) Fixed oils, e.g., animal and vegetable oils.
- (f) Rosin oil.
- (g) Tarry matter.
- (h) Moisture.
- (j) Volatile constituents—loss in one hour at 370° F.

The first five determinations (a-e) call for little comment; they are carried out by well-known standard methods.

(f) *Rosin Oil*.—Recent analyses have shown that this body is seldom present in any reliable lubricating oil, nevertheless we consider that its detection and determination are worthy of special attention and will be considered in detail under grease.

(g) *Tarry Matter*.—This impurity has been found in small quantity in some oils. The determination is carried out on the residue, left after treatment for rosin oil, which consists chiefly of mineral oil and is treated by the method used by Kissling.* This method is adversely affected by the presence of fatty acids and fixed oil and is only intended for mineral oil products.

(h) *Moisture*.—Loss at 212° F. is only determined in the case of light oils, in other cases loss at 370° F. is estimated.

(j) *Volatility*.—This is defined as the loss in one hour at 370° F. The test is carried out on from 0.5 to 1 gram of the oil and is applied in the case of cylinder and compressor oils. The temperature given is that considered by engineers as the temperature to which the oil is subjected when in use, and is intended to show the degree of volatilisation of the oil in practice, in compressors working at 160 lbs. per square inch. To

*Walls & Southcombe: "Theory and Practice of Lubricants," *Chem. Trade Journal and Chem. Engineer*, Feb. 24, 1920, p. 100.

*"Lubrication and Lubricants,"—Archbutt and Doolay, p. 320.

a chemist the test is unsatisfactory and somewhat varying results are obtained on account of difficulty of control. It is a determination which requires the adoption of a standard apparatus.

The following figures show the variations obtained on the same oil by slightly altering the conditions. In the first two tests the oil was heated in an oil jacketed oven with closed door. In the first case the thermometer bulb was immersed in a cup of oil placed on the tray with the samples and kept at 370° F.; in the other the thermometer bulb touched the tray, in the middle of the oven, on which the shallow dishes containing the samples were placed:—

Results:—	(1)	(2)	(3)	(4)	Av.
	%	%	%	%	%
Thermometer in oil ...	2.4	2.3	2.4	2.3	2.35
„ touching tray...	3.4	3.2	3.4	3.6	3.40
Another series of tests were conducted in an ordinary air oven without jacket, giving results as follows:—	(1)	(2)	(3)	(4)	Av.
	%	%	%	%	%
Thermometer in oil ...	3.6	4.4	2.4	4.0	3.60
„ touching tray...	3.0	4.5	3.7	2.4	3.40

From these figures it will be seen that big variations in results are obtained when different methods are used. In the oil jacketed

oven four determinations with either adjustment of the thermometer give good agreement, but the averages vary considerably. In the air oven tests there is a big divergence in individual results, although the two averages are remarkably close and agree with one of the oil jacketed series. On average percentages obtained, about 3.5% would be the accepted result, but on account of the great divergence in the air oven figures the result is unreliable and 2.35 is just as likely to be correct.

Another oil was tested similarly and gave results as follows, with the thermometer touching the tray:—

	(1)	(2)	(3)	Av.
	%	%	%	%
Oil jacketed oven ...	3.8	4.5	4.0	4.1
Air jacketed oven ...	3.0	1.9	3.4	2.8

In these tests the agreement in the oil jacketed oven is not quite so good as with the previous sample, but it is closer than with the air oven. There is a big discrepancy in the average result in the two cases.

The figures given show that some standard method is essential, and we recommend this for the consideration of the Engineering Standards Committee. In the Proceedings of the American Society for Testing Materials, year 1919, p. 732, it is recommended that the tray containing the

TABLE I. MISCELLANEOUS OILS.

No	Description	F. P. Closed Test ° F	Viscosity Bov. Red. Secs per 50 c.c.		Sp. Gr. (<i>a</i>) 60° F	Free Fatty Acids	Rosin Oil	Tarry Matters	Fixed Oils	Volatile		Soap	Ash %
			70° F	200° F						@ 212° F	@ 370° F		
1	Dynamo	354	275	—	.898	Nil	Nil	0.25	Nil	3.5	—	Nil	0.003
2	"	367	360	—	.902	"	"	0.29	"	6.0	—	"	0.002
3	Engine (Light)	361	611	56	.875	Trace	—	—	"	2.4	45.3	—	—
4	" "	369	466	—	.902	Nil	Nil	0.06	"	0.8	—	Nil	0.004
5	Engine (Heavy)	349	1,655	—	.900	"	"	0.13	"	1.3	—	Trace	0.006
6	Machine	408	870	—	.877	"	"	Nil	"	0.4	—	"	0.004
7	"	378	365	—	.866	"	"	0.04	"	0.7	—	Nil	Nil
8	Cylinder	486	—	160	.892	0.2	—	—	0.2	—	2.8	"	—
9	"	495	—	116	.887	Nil	Nil	0.06	Nil	—	1.6	0.06	0.004
10	"	496	—	147	.904	"	"	0.30	"	—	0.8	Nil	0.004
11	"	536	—	251	.910	"	"	0.05	"	—	Nil	"	0.040
12	"	422	—	182	.921	0.6	"	—	"	—	1.7	"	0.142
13	"	496	—	132	.888	0.1	"	—	—	0.2	7.0	—	—
14	Air Compressor	340	466	—	.882	Nil	"	0.05	Nil	3.2	41.1	Nil	0.002
15	" "	369	613	—									
16	" "	343	463	—									
17	Chamber	307	617	—	.871	"	—	—	"	2.2	47.2	"	—
18	Heavy Bearing	347	2,860	98	.919	Trace	—	—	0.4	0.8	12.9	0.8	0.11

TABLE II.

Ref. No.	Flash Point Closed Test °F.	Viscosity		Specific Gravity (a) 60°F.	Free Fatty Acids	Rosin Oil	Tarry Matters	Fixed Oil	Moisture (a) 212°F.	Volatile 1hr. (a) 370°F. on 0.5 to 1.0 gm. in shallow dish
		Boverton-Redwood Secs per 60 c.c. (a) 70°F.	(a) 200°F.							
Light Bearing Oil.										
1	Desired Specification 350 to 400	450 to 600	—	.870 to .900	Nil	Nil	to 0.05%	Nil	—	—
2	—	515	—	.900	..	..	—	—	—	—
3	356	505	—	—	Trace	..	—	—	—	—
4	330	520	—	—	Nil	Nil	—	—	—	—
5	373	640	—	.913	Trace	Trace	0.7%	Nil	—	—
6	366	535	—	.913	..	Nil	Nil	..	—	—
Heavy Bearing Oil										
7	Desired Specification 350 to 450	1500 to 2000	—	.900 to .920	Nil	Nil	to 0.1%	Nil	—	—
8	—	1860	—	.898	..	..	—	—	—	—
9	324	1515	—	—	0.4	—	—	—	—	—
10	435	1627	—	.917	Trace	Nil	Nil	Nil	—	—
11	395	2570	—	.913	Nil	—	—	—	—	—
12	416	1630	—	.896	..	..	..	..	—	—
Dynamo Oil.										
13	Desired Specification 300 to 400	300 to 400	—	.850 to .890	Nil	Nil	Nil	Nil	—	—
14	347	322	—	.899	Trace	..	..	..	—	—
15	349	397	—	—	Trace	..	..	..	—	—
16	338	328	—	—	..	..	..	..	—	—
17	345	300	—	—	..	..	..	..	—	—
18	338	331	—	.900	Nil	Trace	..	..	2.6	—
19	356	390	—	.903	..	..	..	..	0.6	—
Compressor Air Cylinder Oil										
20	Desired Specification Above 400 preferably above 450	Above 130	—	.885 to .900	Nil	Nil	Nil	Nil	—	Not to exceed 1.0%
21	450	150	—	—	..	..	..	..	—	4.1
22	400	171	—	.893	Nil	Nil	Nil	Nil	—	2.0
23	396	62	—	.910	..	2.2	..	..	—	48.8
24	482	122	—	.898	..	Nil	..	..	—	12.8
25	404	175	—	.896	..	..	..	..	—	Nil
26	400	58	—	.893	..	..	..	..	—	3.5
27	405	134	—	.907	..	..	..	..	—	8.8
Steam Cylinder Oil										
28	Desired Specification 500 to 550	200 to 250	—	.900 to .920	Nil	Nil	to 0.1%	Nil	—	Not to exceed 0.5%
29	500	238	—	.902	..	..	Nil	..	—	0.4
30	505	202	—	.906	..	..	..	..	—	1.4
31	575	180	—	.904	..	Trace	..	..	—	1.6
32	515	190	—	.907	..	Nil	..	..	—	0.3
33	540	248	—	.909	..	..	..	..	—	0.4
Crack Chamber Oil.										
34	Desired Specification 400 to 450	550 to 600	—	.870 to .900	Nil	Nil	to 0.5%	Nil	—	—
35	410	545	—	.893	..	..	Nil	..	—	—
36	380	580	—	.885	..	..	..	..	—	—

samples should revolve mechanically during the test.

Having now enumerated the tests we consider necessary to apply to lubricating oils, we may proceed to consider results which have been obtained by examination of different types.

Table I—Miscellaneous Oils—gives data obtained from analyses of oils often used before purchasing on definite specification.

It will be observed that the volatile constituents at the respective temperatures are generally abnormal, the flash point and viscosity figures for any type of oil are erratic.

Nos. 6 and 7 are classed as machine oils, which show considerable difference in viscosity and flash point. No. 9 shows a very low viscosity for a cylinder oil. No. 12 is an exceptionally thick, heavy oil containing free fatty acid, and gives an appreciable amount of ash, consisting chiefly of oxide of iron, its flash point and viscosity are not so high as might be expected from the appearance of the oil. Nos. 14, 15, and 16 are so called compressor oils which are quite unsuitable, and emphasise the necessity of standards being laid down. No. 18 appears to be an artificially thickened product.

Table II.—This table gives results obtained from oils, supplied more recently, under certain specification requirements as shown.

Above figures prove that there should be no difficulty in obtaining oil to comply with the requirements of these specifications. In this respect the compressor and air cylinder oils are worthy of special attention. The percentage of components volatile at 370° F. is an important feature, since a high proportion gives rise to contamination of the air, and possible explosion. The viscosity has a direct bearing on the lubricating power, and an unsuitable oil is sometimes made to meet viscosity requirements by compounding soap with the oil, but this will readily be detected on analysis. The flash point is obviously a most important feature.

Fixed oils have never been found present in lubricating oils recently examined, but some years ago one cylinder oil which was usually recognised to give excellent results in practice contained about 7 per cent. of animal oil or fat.

Light bearing, heavy bearing, and dynamo

oils call for little comment as they generally meet requirements.

Compressor oils require special attention. No. 23 is an oil which it would be dangerous to use in a compressor—it contains rosin oil and all the other important figures condemn it. Nos. 24, 26, and 27 also are unsuitable and would not be accepted.

Steam cylinder oils are generally good, but No. 36 is too light an oil for crank chamber purposes.

Grease.—Under this heading we find, as will be seen, mixtures of great variety. The percentage of water, as determined by loss at 212° F., has caused much discussion, and in some cases this loss has been so high that it has been necessary to determine the water otherwise, and a distillation method at once suggests itself.

Addition of paraffin oil to the grease, before distillation, sometimes proves satisfactory, but very often frothing occurs and spoils the determination. A successful distillation was always obtained when Xylol was used—boiling point 140° C.

100 grams of the sample are weighed into a wide-necked flask of about 500 cc. capacity, 100 cc. of Xylol are added, and the flask is then connected to a condenser and heated carefully on a sand bath. Once distillation commences there is rarely any necessity for great attention. The water and light oil distil easily and are completely obtained in the first 70 to 80 cc. of distillate, which is collected in a measuring cylinder. The water separates readily and the volume can be read off. The difference between water by distillation and loss at 212° F. is due to the presence of light volatile oil. This latter is often present owing to the fact that crude petroleum oil has been used in the manufacture.

The use of this crude oil may account for some, if not all, of the resinous bodies and asphalt found in certain samples of grease. In such cases the manufacturers sometimes repudiate the presence of these bodies as they have not been added intentionally.* According to Holde badly refined mineral oil may contain as much as 3.5% of resins soluble in 70% alcohol, and these resins fail to give the violet colour test with acetic anhydride and sulphuric acid.

In other instances resinous bodies are found present in considerable amount

*C. F. Mabery. *The Mining Journal*, March 13th, 1920, p. 207. "Lubrication and Lubricants"—Archbutt & Deeley, 3rd Edition, p. 317.

(usually the colour test fails), and they can only be considered as having been added intentionally. Other investigators have found in crude petroleum oil ill-defined substances resembling resin.

The detection and determination of rosin oil and resins in oil and grease are worthy of special attention. The Liebermann Storch reaction, i.e., the fugitive violet coloration produced by the acetic anhydride, sulphuric acid test, is generally relied on for their detection, and a negative result taken as indicating their absence. The reliability of this test has frequently been suspected by the authors, a negative result has been obtained in cases where on further examination rosin has been separated and identified as such. In one instance as much as 10% of rosin oil was obtained from an oil which failed to give a violet coloration test on the original. Storch's method of determination^{*} has proved satisfactory. This consists in warming a weighed portion of the unsaponifiable oil with alcohol (95% by weight) in amount equal to 20 to 50 times the possible weight of rosin oil present. On cooling the alcoholic solution is filtered into a tared beaker and the surface only of the oily residue washed with 90% alcohol. The alcohol is gently evaporated off on a water bath and the residue weighed. This residue consists of the rosin oil and a certain amount of mineral oil which is dissolved by the alcohol. A second treatment is then given with a less amount of alcohol, and, naturally, the weight will be less owing to the smaller quantity of alcohol requiring less mineral oil to saturate it. From these two weighings a figure is obtained showing how much mineral oil X cc. of alcohol will dissolve, and this allowance is deducted from the second weighing. It is sometimes advisable to make a third alcoholic extraction and evaporation.

Professor Finkener's method of digesting the oil in one volume of chloroform and ten volumes of alcohol (e.g. 0.518) is very reliable. Ten volumes of this mixture at 23°C. dissolve one volume of rosin oil from mixtures of rosin and mineral oils, without dissolving any appreciable amount of mineral oil. The residue should always be oxidized with nitric acid (e.g. 1:2) followed by a water washing and treatment with petroleum

ether which dissolves out unchanged mineral oil, the oxidized rosin being insoluble.*

In grease the saponifiable rosin may be present either as rosin acid or a soap; in any case the saponifiable content is examined apart from the unsaponifiable which is submitted to the above alcohol treatment.

When rosin soap is found in grease it usually happens that no other soaps of the fatty acids are present, and it is therefore seldom necessary to effect a separation of the fatty and rosin acids. When the necessity does arise we recommend applying Twichell's method† in which the aliphatic acids, in alcoholic solution, are converted into ethyl esters by the action of hydrochloric acid gas. The esters and rosin acid are next dissolved in petroleum spirit and separated from the hydrochloric acid solution. The rosin acid is then converted to soap by the action in the cold of a small amount of potash dissolved in dilute alcohol. This separates readily from the petroleum spirit containing the esters, it is run off, acidified, and the separated rosin acids collected and weighed.

Other constituents which may be found in the unsaponifiable oil are wax alcohols. These are liable to be confounded with rosin oil. An excellent indication of the presence of these bodies is the effect they have on the solubility of mineral oil in ordinary alcohol.‡ When wax alcohols are present, even in such small proportion as 5%, the unsaponifiable substances, which include the mineral oil, are readily soluble in rectified spirit (95%).

The determination of free fatty acid, fixed oil, soap, mineral filling, and examination for grit call for little comment as they present no difficulty to any chemist. Free alkali has been found in some samples of grease, it is usually present as free lime, and is probably intended to mask the presence of free fatty acid. In cup grease we have invariably found the mineral filling to be carbonate of lime, though in antifriction grease talc is often used.

The heat test on sieve is useful for a cup grease. About 5 grams of the grease are placed on a piece of 200 mesh screening con-

* McIlhenny, *Jour. Amer. Chem. Soc.* XVI, 1895, p. 387.

† *Jour. Soc. Chem. Ind.*, 1891, 10, p. 804, and Allen Vol. II, p. 77.

‡ Nash "The Analyst," 1903, p. 1.

* *Jour. Soc. of Chem. Ind.* VII, 1898, page 120.

"Analyst," VIII, 1898, p. 71.

tained in a Gooch crucible provided with a cover, and are heated in an oil bath fitted with a glass or mica front. By means of a thermometer alongside the test the temperature is noted at which the grease commences to drip through. Heating is then continued till the grease ceases to drip through when the screen is examined.

A good grease should all run through in a satisfactory range of temperature, e.g., light grease 190°—210° F. and heavy grease 220°—250° F.—and should not leave an appreciable residue on the sieve. Some greases leave a considerable residue indicating separation of the mineral oil from the soap and filling.

Softening Point.—The object of this test is to determine the temperature at which the adhesive power of the grease to metal fails to withstand a pressure of 1½ inches of mercury. The apparatus is described by W. Fisher in the Proceedings of the American Society for Testing Materials, Vol. 11., 1911, p. 699, and has been used for several years in the Consolidated Goldfields and Rand Mines Laboratories.

A cylinder or column of grease ¼ inch diameter and ¾ inch in height is contained in a thimble provided with a lateral hole at the base of the grease column. The thimble is screwed into the base of an iron cup which is immersed in an oil bath. A thermometer is introduced into the cup, the bulb being on a level with the grease column. Mercury is then added to the cup to a depth of 1½ inch from the base of the grease column. The oil bath is then gently warmed and the temperature noted at which the grease is displaced and rises sharply to the surface of the mercury. A light grease will often not stand the upward pressure at ordinary temperature; in this case the depth of mercury at which it rises to the surface is noted.

This is a most useful and practical test, but up to the present no definite standards have been published and the results are empirical. With some experience a good knowledge can be gained of what should be expected from various classes of grease.

Three instances may be given here of rock drill lubricants. Sample A was found to be much more economical than Sample B, a tin of the former giving about three times the service that the latter gave under similar conditions. Sample C is an entirely different type, and was said to give satisfactory results:—

	"A" Per cent.	"B" Per cent.	"C" Per cent.
Fixed Oils (Animal and Vegetable) ...	Nil.	Nil.	14.7
Rosin—saponifiable ...	Nil.	3.9	Nil.
Rosin—unsaponifiable	2.0	3.4	15.7
Free Fatty Acid ...	0.3	0.8	0.8
Free Mineral Acid ...	Nil.	Nil.	Nil.
Free Alkali ...	Nil.	Nil.	Nil.
Water by Distillation	Nil.	0.1	Nil.
Ash ...	0.03	0.35	0.02
Soap ...	Nil.	Nil.	Nil.
Mineral Hydrocarbons (Mineral oil, paraffin wax and vaseline—by difference) ...	97.67	91.45	68.78
	<u>100.00</u>	<u>100.00</u>	<u>100.00</u>
Specific Gravity (60°F)	0.905	0.917	0.913
Sp.Gr. (60°F) of Mineral Hydrocarbons...	0.903	0.912	0.900
Softening Point ... 21°C.		Does not form column in thimble.	Forms column but will not stand any mercury pressure.
Softening Point of Mineral Hydrocarbons... 21°C.		Forms column but will not stand any mercury pressure.	25°C.

From comparisons of analyses "A" and "B" we would be unable to draw a conclusion as to why "A" should be more serviceable than "B." The difference is due to the adhesive power, which is shown by the instrument described.

The mineral hydrocarbons are of different types and showed variation in behaviour when subjected to distillation.

The difference between the softening points of the original sample and mineral hydrocarbons in "C" is due principally to the removal of the fixed oils. The constituent in "C" (15.7%) on oxidation appeared to consist of rosin. The violet reaction previously referred to could not be observed in the test on this extract, but otherwise it showed characteristic properties of rosin. The specific gravity was 0.946, which is high, and a high gravity is typical of rosin oil or higher alcohols. If the latter had been present the solubility of the mineral oil in ordinary alcohol would have been much greater than was found. The rosin extracts of both "A" and "B" gave the fugitive violet coloration.

Pitch and asphalt are not found in good cup grease, some anti-friction greases have been found to contain asphalt, and both may be present in rope dressing. They can be separated from the unsaponifiable constituent, but their determination cannot be considered as highly accurate owing to lack of knowledge regarding their chemical properties.

Pitch and asphalt together* are estimated as follows:—Digest 5 grams of the unsaponifiable matter in 25 cc. of ether, then add very slowly with constant stirring 12.5 cc. of alcohol (96%). This precipitates the pitch and asphalt, which is allowed to settle for several hours, filtered and washed thoroughly with alcohol ether (1:2). The insoluble matter is next digested on the filter with boiling benzol which dissolves pitch and asphalt. The filtrate is collected in a tared dish and is evaporated and weighed. This extract may contain some solid paraffin which may be detected by boiling with 96% alcohol when, on cooling, the paraffin, if

* "Lubrication & Lubricants," Archbutt & Deely, 3rd Ed. p. 318.

present, can be seen separating out.

Having described methods of analysis we may now consider different varieties of grease giving analyses of typical samples.

1. *Cup Grease*.—This is the most important type of grease and may be subdivided into three classes:—

- (a) Light.
- (b) Heavy.
- (c) Extra heavy.

All these should be free from grit, rosin oil, and mineral acid. The free fatty acid should not be more than 0.1%; water and mineral filling—apart from soap base—should be low, certainly not more than 3%. Some specifications call for a much smaller quantity, but allowance must be made for manufacturing difficulties. In a light grease the lime soap should be about 17–18%, and mineral oil about 77%. Heavy grease should have about 20–22% of lime soap, and mineral oil about 74%. Extra heavy grease should contain about 25% of lime soap and mineral oil about 70%.

The following are typical examples of cup grease analysed:—

	LIGHT		HEAVY.			EXTRA HEAVY.
	1	2	3	4	5	6
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Water by Distillation	2.7	1.6	2.9	2.4	1.0	4.6
Lime Soap	17.5	18.1	20.1	22.1	21.8	25.7
Mineral Filling	1.5	1.1	1.6	2.6	1.8	3.0
Free Alkali	Trace	Nil	Trace	Trace	Nil	Trace
Free Fatty Acids	"	0.1	"	"	0.1	"
Fixed Oils	Nil	Nil	Nil	Nil	Nil	Nil
Rosin Residue	2.0	5.3	2.1	1.8	3.5	1.6
Grit	Nil	Nil	Nil	Nil	Nil	Nil
Mineral Oil (by difference)	76.3	73.5	73.3	71.1	71.8	65.1
	100.0	100.0	100.0	100.0	100.0	100.0
Softening Point	178°F	179°F	182°F	194°F	190°F	202°F

It will be seen that all these contain some rosin. Nos. 2 and 5 are higher than are acceptable. In all of these the rosin was extracted and identified by the oxidation test previously quoted, generally the fugitive violet test was unsatisfactory even on the extracted material.

We are informed that Nos. 1, 3, 4 and 6 give excellent results in practice.

II. *Anti-friction Grease*.—This is a type entirely different from cup grease, it is a much cheaper article, and big variations occur in the composition. A few points are worthy of attention. The mineral filling and rosin are usually much higher than in

cup grease and the soap content varies considerably. Analyses are given below.

In the cases of C, D, E, and F, both the loss on drying at 212°F and the water by distillation with Xylol are given, and show that these greases contain a considerable proportion of light volatile oil, this is especially marked in E and F. A is a good type of grease, resembling in many respects a heavy cup grease, but contains a fair amount of rosin and some asphalt. B contained a large amount of rosin lodies, the mixture was not homogeneous and separated into layers. C and D contain a small percentage of light volatile oil and a fair amount of

	A	B	C	D	E	F
Water by Distillation	8.7	6.1	5.0	6.5	2.5	3.0
Lime Soap	24.8	6.1	7.0	10.0	17.5	15.5
Mineral Filling	1.6	Nil	3.5	2.6	4.3	4.5
Free Alkali	Trace	2.4	1.0	Trace	Trace	Trace
Free Fatty Acid	0.3	0.1	Nil	Trace	Trace	Trace
Fixed Oils	Nil	Nil	Nil	Nil	Nil	Nil
Rosin Bodies	6.7	41.5	10.0	10.4	7.0	9.0
Asphalt	1.0	—	—	—	2.2	1.9
Grit	0.2	Nil	Nil	Nil	Nil	Nil
Mineral Oil (by difference)	56.7	43.8	73.5	70.5	66.5	66.1
	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>	<u>100.0</u>
Total Loss at 212° F	—	—	10.0	13.6	22.5	23.4
Softening Point	—	—	196°F	247°F	143°F	120°F
Heat Test on Sieve	satisfactory	unsatisfactory	—	—	—	—

rosin—it will be noticed that C contains free alkali. E and F are very similar and contain a large percentage of light volatile oil, the rosin constituent is present in fair amount, and they also contain some asphalt.

III. *Rope and Gear Dressings.*—Incidental to lubricants are gear and rope dressings. Typical analyses are given below. As will be seen they are very complex preparations and show big variations in composition:—

ROPE DRESSINGS.

I	%
Water	19
Ash	5
Sugars	15
Organic acids combined with lime ...	10
Asphalt	10
Tar, Tar Products, and Mineral Oil by difference	41
	<u>100.0</u>
II.	%
Water	18.1
Fixed Oils	2.2
Lime Soap	0.5
Free Fatty Acids	0.3
Mineral Filling	13.4
Asphalt	11.5
Rosin Bodies	5.8
Mineral and Tar Oils (by difference)	48.2
	<u>100.0</u>
III.	%
Water	Nil
Lime Soap	2.7
Free Organic Acid	5.2
Mineral Filling	Trace
Asphalt	7.4
Rosin Bodies	35.2
Mineral and Tar Oils (by difference)	49.5
	<u>100.0</u>

GEAR DRESSING.

	%
Water	Nil
Fixed Oil	2.5
Lime Soap	2.8
Free Fatty Acids	0.5
Mineral Filling	Nil
Asphalt	26.9
Rosin Bodies	1.8
Pitch	4.7
Mineral Oil (by difference)	60.8
	<u>100.0</u>

HARD GREASE.

	%
Loss at 212° F.	2.8
Lime Soap	29.0
Mineral Filling (CaCO ₃)	0.3
Free Fatty Acids	10.1
Fixed Oils	Nil
Grit	Nil
Wax Alcohols	5.0
Mineral Oil (by difference)	52.8
	<u>100.0</u>

I. appears to consist of a mixture of Stockholm tar, bituminous matter and molasses. It is an exceptional mixture and is said to give satisfaction. The hard grease is a most unusual material, it has a high soap content, and has an exceptionally high proportion of free fatty acid (stearic acid), and it will be noticed that wax alcohols are present. The asphalt found in above samples was asphalt insoluble in normal petroleum benzene and can be separated from pitch and other tar bodies.

The authors hope that this paper will arouse interest in a subject which they think has been somewhat neglected locally.

As was stated at the outset the paper deals with the chemical aspect. It would be of great interest if someone having details of physical tests would come forward with a paper dealing with the subject from that point of view.

We desire to thank the Rand Mines, Ltd., and Mr. K. L. Graham, Consulting Metallurgist, for permission to publish the figures given.

Mr. H. R. Adam thought the Society was greatly indebted to Messrs. Watson and Bell for their very valuable paper. The paper was one which would appeal very much to the technical chemist; it contained the kind of data they wanted. The records were those of actual experimental work; very detailed records, as could be seen from the figures. One of the things that struck him was that the work of the chemist in connection with such materials was very much of a policeman's duty; what he meant was, the chemist was largely concerned with looking for what constituents were harmful or useless, and the results had very little to say about the actual lubricating properties of the oil. Of course, that was not the chemist's fault.

He would like very much to know what the basis was on which the authors had given those specifications. The only remark made under that heading was that such products had given great satisfaction in actual practice. Of course, that was useful, but he did not know that it could be called very scientific, and he would like to support the authors' plea that this was a matter for the Engineering Standards Committee.

The viscosity test, he supposed, from the lubricating point of view, was the most important. He would have thought that viscosity tests would have been made at still higher temperatures than those given by the authors in their tables, because, he supposed, after all, the idea of the viscosity test was to give information as to the adhesion of the oil to the metal surfaces at the temperatures found in practice. However much the friction was reduced, it was not much good if it did not adhere as a continuous film. That was, he thought, put rather vaguely, the idea of the viscosity test. If they were working with the oil or lubricant at a higher temperature than given in the tables, then they certainly ought to have viscosity tests at the temperature in use. Obviously, as the writers said, it was easy to increase the viscosity at ordinary temperatures by adding

scap, or emulsions of soap to the oil or grease.

He was rather interested in what was called the volatility test, which must be rather an important one as regards compressor oils. He was wondering whether a distillation method, such as was used in connection with the grease, might not be applied even although the temperature was fairly high, about 370°F.

Some of the data in connection with the greases was of very great interest. There was plenty of room here for disposing of otherwise unsaleable products. The idea with these lubricants, generally speaking, was to use the lubricating properties of heavy mineral oils, the latter being made highly viscous by the incorporation of a lime soap. What was the lubricating effect of the soap?

There was a good deal of work being done now in order to try and arrive at some really fundamental facts with regard to the theory of lubrication. He was rather disappointed to find that none of the oils examined by the authors contained any vegetable oil. Some of the recent work done was very interesting; he thought the authors referred to it in their paper. The introduction of small proportions of vegetable oil—*e.g.*, castor oil—was recommended by some authorities, and the effect with regard to the reduction of friction seemed to be rather extraordinary. He noticed a great deal of work was being done in connection with the blending of castor oil with mineral oils at the present day. Apparently, however, these ideas were not yet sufficiently established, as the authors had not included such additions in their specifications.

He thought that was all he could say at the moment on the subject. He had much pleasure in proposing a vote of thanks to Messrs. Watson and Bell for their valuable paper.

The President hoped they would have a complementary paper on the physical side of oil testing, enlarging on physical specifications for lubricating oils and greases. He thought the paper by Messrs. Watson and Bell had emphasised the necessity for chemical examination by a qualified chemist. At the same time one could not help sympathising with the manufacturers of these oils and greases who had to produce within these rather terrifying limits. He thought the authors had presented a valuable paper, and wished to add his appreciation.

SYMPOSIUM: MINERS' PHTHISIS.

Dr. Orenstein in introducing a paper contributed by Dr. W. E. Gye, said that this gentleman was Senior Pathologist of the National Institute for Medical Research, in London, which was one of the activities of the National Council for General Research, which has done such good work, as they knew, during the war. Dr. Gye was visiting here for about a fortnight a few weeks ago, and had been working on miners' phthisis from the standpoint of the causation of the disease, or perhaps more correctly, he had been working on silica as a cause of various diseases, and in that connection, of course, became very much interested in the principal disease caused by silica—miners' phthisis. They would recollect that the Symposium on Miners' Phthisis had been running now for some months, and that very early in the symposium—he believed on the first night, as a matter of fact—Dr. Mavrogordato very kindly read to them a very interesting contribution on the mechanism of the production of that disease, if he might so say, in which he had recapitulated the various factors.

Perhaps, for the better understanding of Dr. Gye's paper, it would be well if he briefly indicated to them what essentially miners' phthisis was. Essentially miners' phthisis was, in technical language, a "fibrosis," which really meant the change of lung tissue into scar tissue. The lungs, of course, were organs primarily intended to oxygenate the blood; and, in order most efficiently to carry out that function, were arranged by nature in such a way as to expose the blood in the blood vessels to the maximum amount of air in a given space. Nature, of course, arranged things very cleverly; it arranged the lungs into organs which were perhaps best comparable to the ordinary rubber sponge—a maximum of air cells, with the minimum of division walls, and in those division walls blood vessels which, in the case of the lungs, were mostly small and consisted of a single layer of cells, the blood being confined in a tube made up of a single layer of cells, particularly thin in those blood vessels known as capillaries. Thus the blood had a very ready contact with relatively large volumes of air, and the interchange of oxygen and CO_2 easily took place.

If they reduced the volume of this cellular structure—if they obliterated a very large number of those cells by changing them

into scar tissue, it was obvious that, to that extent, a lesser volume of air would come into contact with the blood, everything else being equal. Scar tissue, as everyone knew, was hard; it contained relatively very few spaces, and those spaces were, of course, infinitesimal; consequently air could not penetrate into those spaces to any extent, and the interchange of oxygen and CO_2 could not properly take place in scar tissue.

It had always been rather a mystery as to why silica caused scar tissue formation. They were aware, of course, that if they cut their finger, or hand, or if they inserted a foreign substance into their skin, or into a muscle, the effort of nature to heal the injury was by means of scar tissue. In just the same way as when they cut the bark of a tree, the effort of nature there was to form a callus, which was essentially the formation of scar tissue on a tree. There was some absorption and final equilibrium in the substance in which the original injury took place. There was very seldom in the higher mammals—particularly man—a regeneration of the original tissue; there was nearly always substitution of scar formation. Therefore, it was easy to jump to the conclusion, one might say, that the inhalation of a foreign substance such as silica would cause an injury, followed by scar tissue formation. Well, it was a curious fact that this particular relatively enormous scar formation did not take place when they inhaled other substances which one might assume *a priori* would also injure the cells of the lungs, and thus cause the formation of scar tissue to repair the injury. Silica did that to an extent very much greater—enormously greater—than any other substance known which was inhaled into the lungs. Furthermore, the greater the injury to a given tissue the greater the scar tissue formation, generally speaking; that was to say, if they put a pin or a sharp needle into their hand, the amount of scar tissue which would form in connection with the repairing of that puncture was, of course, very much less than if they drove a nail in or if the cut was an inch long.

It was owing to the work done in South Africa largely by Dr. Moir that it was now known that the particles of silica which caused this surprisingly great amount of scar tissue were the smallest. They could not, of course, drive into the cells of the lungs a marble or a lump of coal. Obviously, the particles must be quite small to

enter the cells of the lungs at all, and to damage them; but the particles which entered the air spaces of the lungs and which did the most damage were infinitesimally small as compared with the size of the air spaces, and the so-called large particles were also very much smaller than the size of these spaces; yet the so-called large particles did not produce the damage that the small ones did.

That is one argument why the mechanical theory of miners' phthisis is not quite acceptable. Furthermore, there was a curious phenomenon which had only been observed really with any certainty since the formation of the Miners' Phthisis Medical Bureau, with the consequent examination of people at periodical intervals, and a comparison of records carefully kept from one examination to the other: it was that when a man got a certain amount of pure silicosis, pure formation of scar tissue, due to silica, without tuberculosis, if the amount of fibrosis reached a certain point, in a certain proportion of these men, even if they dropped mining and did not any longer inhale silica to any extent beyond the amount that everyone inhaled who was not working underground, the disease progressed. That again was incompatible—not quite compatible, perhaps, if not entirely incompatible—with the hypothesis of the purely mechanical injury done by silica particles. He took it this argument required no great elaboration. If they stopped inhaling silica, and the scar formation progressed why? What was going on, if it was purely mechanical and due to insoluble silica?

Furthermore, it had been an observation which had been taken for granted on the Rand for many years that the native was relatively immune to silicosis. It had been said that the reason was that he was not exposed to the most dangerous period of silica inhalation—that was, the periods of blasting—to the same extent as the white man. Well, that of course was not quite true under present mining conditions, and those of the last eight or ten years. The majority of white men were also not very greatly exposed to those dangerous times of blasting, and the fine dust resulting. It also still remained to be proved, of course, that the dust produced by blasting was essentially more dangerous than the dust produced by high-speed drilling. It was certainly a fact that dry drilling, as shown by the cinema film taken some time ago—which many of them had seen—produced in

a few seconds a very large quantity of very minute dust invisible to the ordinary eye and which could not be determined to a certainty by the available methods of examination, such as the gravimetric and the counting method—the konimeter method—for the reason that the production of such dust might take place over only a very short time, and yet the quantity be very great, and in that particular short time it was, of course, a very small chance that the determination would be made, unless the arrangements had been pre-determined and the dust production deliberately set about. They would re-call that on that film it was shown by the artificial light—equal to about 200,000 candle power—that clouds of fine dust were produced by drilling without water for ten or twenty seconds. At twenty seconds, with that light, the photograph was entirely fogged by dust, although, to the naked eye of the observer it was not visible. If such periods of twenty seconds occurred several times in a shift, of course a very large amount of dust would be inhaled by the men in the immediate vicinity of the drill—and the men in the immediate vicinity of the drill were, nine times out of ten, natives. So that they would, in machine drilling, probably be exposed at least as much as the white men.

By a process of elimination one could say that the only essential difference between a native and the white man was the fact that a very large percentage of the natives who worked on these fields periodically retired to their homes and only worked a certain length of time underground, and then had, perhaps, an equal or a longer length of time at home. Eliminating East Coast boys, whose average stay he had been given to understand was fifteen months, the fact that on these fields there were recruited every year rather more natives than were on the average at work, that would give one the idea that the average stay all along is rather less than a year, with an absence of some months between each engagement, apparently in a large number of cases. One might from that quite reasonably argue—he did not put it forward as an explanation, because he did not know of any definite data on the subject—that the periods of long rests between periods of exposure, provided miners' phthisis did not progress to a given point, and provided there was not so much silica in the lungs as to cause damage according to the theory which Dr. Gye put forward in his paper, provided that point

had not been reached, something took place during the rest period which neutralised the ill effects of silica—always assuming the amount of silica in the lungs did not come up to that point where it cannot be neutralised any more by any period of rest.

Dr. Mavrogordato, in his interesting paper, the result of long and painstaking research, had pointed out to them that infection with organisms, with germs, played a very large part in the production of the disease of miner's phthisis, apart from tuberculosis. They would recall that Dr. Mavrogordato had put forward one theory. Dr. Gye had now put forward still another theory. They would recall that he (the speaker) in his introductory remarks in opening the Symposium, had said that, to his mind the solution of the problem of miners' phthisis required the co-operation of several branches of scientific research and investigation. In Dr. Gye they were fortunate to have the combination—a medical man who had been a chemist before he became a medical man, and who had gone somewhat into the chemical explanation.

He would now read Dr. Gye's paper, and if any point was not quite clear, they might discuss it later on, or at a subsequent meeting.

Dr. W. E. Gye (*National Institute for Medical Research, London*): It is a great pleasure to add my quota to the symposium on "Silicosis," though I can contribute nothing of direct practical value.

The two questions which Dr. Kettle and I have endeavoured to answer are:—

- (I) How does silica dust cause the injury to lung tissues which ends in fibrosis; and
- (II) What is the explanation of the undoubted association of tuberculosis with silica dust inhalation.

These two questions will be taken in order.

(I) Whenever this question has been faced at all the solution has generally been assumed in the physical properties of silica dust. Too much emphasis has been laid on the sharpness and insolubility of silica particles. We now know that the size of the injurious particles is so small that "sharpness" can be neglected, and consequently most investigators have abandoned the idea that the silica injures the lung in a directly mechanical way. The manner in which the dust enters the lung really precludes this. Dr. Mavrogordato in his article has already

described this, and therefore nothing more need be said beyond repeating that the dust is carried from the air sacs into the lung substance by cells and that therefore of necessity the lung tissue is protected against mechanical damage by the enclosure of the dust particles in the soft "scavenging" cells.

There still remains, however, a good deal of confusion on the question of insolubility.

(Dr. Orenstein said he might just explain that the minute particles of silica were very small; they got into the air passages and were immediately engulfed by tissue cells. They would remember Dr. Mavrogordato showed them photographs of the process. The cells entirely engulfed them, and surrounded them by a gelatinous protoplasmic mass, and then carried them into the lung substance. Dr. Orenstein then completed reading the paper by Dr. Gye.)

The subject may be discussed first by a reference to general principles.

In order to bring about a chemical reaction in a test-tube the inter-acting substances must be brought into the most intimate contact, which is provided by solution. Perfectly dry sodium chloride and dry silver nitrate may be mixed intimately and kept in contact indefinitely without a chemical change occurring. The addition of water brings the salts into solution and immediately insoluble silver chloride is formed. This general principle is applicable to the body. Before a substance can exert an appreciable and continuous effect on living tissues the contact must be molecular, or at least subparticulate, that is colloidal. We recognise this in practice in our methods of combating poisons. When, for example, a person is poisoned with oxalic acid, we administer as soon as possible lime water in the hope of converting the soluble oxalic acid into insoluble calcium oxalate. This of course is, strictly speaking, outside the body. An example of the same principle may be given, however, in which the poisonous substance is put directly into the tissues. The barium ion is very poisonous to mammals, the lethal dose of barium chloride for mice, let us say, being parts of a milligramme. Now BaCl_2 is a soluble substance and we know that its poisonous properties are due not to the chlorine ions, which are an abundant normal constituent of the body, but to barium. Barium sulphate, an insoluble salt, may be injected in very large doses without producing any injurious effects.

This general principle, viz., that a substance is useless to the tissues unless molecular contact is established, is seen also in the processes of digestion. Insoluble food (e.g., egg albumin) is broken up into relatively simple soluble substances before absorption takes place.

The only instance I can call to mind in which insoluble material can cause appreciable injury is where the hollow viscera or conducting tubes in the body become blocked; such as, for example, the impaction of a stone in the ureter.

This may appear to be a laboured argument, but the manner in which these points have been consistently overlooked warrants a brief statement of principles which may be found in any text book of physiology.

It is thus probable that either (1) the silica is slowly converted into an injurious substance by the action of the body cells or fluids, or (2) that the silica inhaled is not the actual poisonous substance but that it is accompanied by a soluble material which has not yet been recognised. The first conclusion is almost certainly the correct one.

What is the probable soluble poisonous compound into which SiO_2 may be converted? Again, to answer this question it is well to take a wide view of the part played by silica in the vegetable and animal kingdoms.

When a plant is ashed silica is almost always found in the ash. Some plants (e.g., oats, barley, etc.) contain a relatively enormous quantity—often as much as 10 per cent. of the ash consists of SiO_2 —others much less. How does the silica get into the plant? It must be absorbed from the soil and it is not merely reasonable, it is almost compulsory, to assume that it is only the soluble forms of silica which can be absorbed. The common soluble compounds of silica are the alkaline silicates and soluble colloidal silica. Chemists have assigned the following formulae to these: Na_2SiO_3 , K_2SiO_3 , and $\text{Si}(\text{OH})_4$; it must be understood, however, that these formulae are merely conventions. The last substance, frequently described as silica acid, is in reality the soluble colloidal form of SiO_2 . Silica (SiO_2) may unite with water in almost any proportion from $\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ to roughly $300 \text{ SiO}_2 \cdot \text{H}_2\text{O}$. The first of these exists as a clear colourless solution, the last is the precious stone opal. The intermediate compounds possess physical properties which vary according to the proportions of loosely bound

water: the smaller the proportion of water the more solid the compound.

Now soluble colloidal silica is a constituent of soil. It exists in small quantities and may be produced either by means of complex chemical changes which occur in soil humus, or, as has been demonstrated, by the activity of soil bacteria. The plant absorbs the colloidal silica, builds it up into its tissues, and when the plant dies and decomposes SiO_2 is once again restored to the soil.

Animals consume plants, and in this way small amounts of silica pass into the animal body: part of it is retained and part is excreted by the kidney, liver and intestine.

It can be seen therefore that silica circulates in nature, and that the circulation depends upon the ready formation of a soluble compound. May not this compound be formed in the lungs of men who inhale fine silica dust?

The direct proof of this would appear to be a relatively easy matter, but in reality it has proved to be very difficult.

We are therefore compelled to fall back upon indirect methods, the first of which is a careful study of the action of colloidal silica on the body.

When a small dose (e.g., 1 mgrm.) of $\text{Si}(\text{OH})_4$ is injected under the skin of a mouse an inflammatory reaction is brought about: the blood vessels at the site of injection become dilated and pour out fluid and cells which form a flat yellowish swelling. Careful microscopic examination of the lesion shows that the cells which come into contact with the concentrated solution of silica are obviously damaged and many are killed. When the dose is smaller and the injection is repeated the lymphatic drainage of the area is deranged, the lymphatic channels becoming blocked by accumulations of cells mostly lymphoid but some endothelioid. The final result of the process is the production of fibroblasts which eventually form fibrous tissue.

Intraperitoneal injections of relatively small doses of soluble silica kill an animal. The substance acts upon the peritoneum, but the manner in which death is brought about has not yet been determined.

When an animal is injected intravenously with colloidal silica in doses of roughly 1 mgrm. to 10 grms. body weight the animal dies in a few minutes of general clotting of the blood. Here it has been determined that the action is upon the cells which line

the blood vessels. Smaller doses, e.g., 10 mgrms. for a rabbit, may be injected intravenously daily for months without any apparent effect upon the health of the animal. If the animal be killed after six months of such treatment, however, it is found that the liver, spleen, and kidneys have become fibrosed. That is to say that small doses of soluble silica are able to exert an effect upon the organs mentioned which corresponds fundamentally with the lesion induced by finely divided silica in men suffering from miners' phthisis. It has been shown that the cells which are primarily affected—the fibrosis is merely a consequence of cellular injury—are the endothelial cells which normally provide the active phagocytic cells which clean up inflammatory areas. The dust cells of the lungs, which play the active part in carrying dust into the lung, are derived from the cells of the lung capillaries. In silicosis these cells are injured and are finally killed by the load of silica which they carry. This process has been described by Dr. Mavrogordato. The probability is that they are killed by the minute quantities of soluble silica produced within them by the action of their faintly alkaline protoplasm on the silica dust. The soluble silica acts also on the endothelial cells lining the lymph channels which finally become blocked. Fibrosis takes place and eventually the so-called silicotic nodule is produced. The long period of time that it takes for the development of fibrous nodules is easily understood if we suppose that a continuous supply of soluble silica is constantly formed from the particles of SiO_2 which lie in lymphatic channels.

From the above consideration of the problem of silicosis it follows that the fine dust is more dangerous than the coarse dust, and that, therefore, the practical problem before engineers is the effective removal of the finest particles of silica. Since ultra-microscopic particles of dust are produced in the process of grinding and blasting, and since these constitute the most dangerous part of silica dust, it would appear that neither koniometric nor gravimetric methods of estimation are likely to yield satisfactory information as to the efficiency of preventive measures.

(II) What is the explanation of the association of silicosis with tuberculosis? The question cannot yet be satisfactorily answered. The effect of silica in damaging

endothelium which is a normally protective cell against tubercle bacilli, and the blocking of lymphatic channels which drain away products of metabolism, together constitute a formidable handicap to the protective mechanism by which the lungs deal with infection. It is not yet possible, however, to state in precise terms the process by which silica predisposes to tuberculosis. Research upon this point is now being eagerly pursued in England and in America.

Dr. Orenstein said there were two points Dr. Gye had mentioned when he delivered his paper before the Witwatersrand Branch of the British Medical Association. He mentioned that in the early days of attempts at tissue fixation—that was to say, preparing tissues for microscopic study, hardening them, one might say—Una, a worker in that field, used silicic acid as a fixative—that was to say, it hardened and fixed tissues. It was an interesting point. Of course, that was outside the body. One of the things that happened to an individual cell in connection with silicosis was a process comparable with the hardening process to which the microscopist subjected tissues, that enabled him to cut thin sections and to preserve tissues from the changes which would otherwise take place. That silicic acid had the property of preservation and hardening of tissues was a matter of interest. Another thing Dr. Gye had mentioned was that beer contains large quantities relatively of soluble silica; whisky, being a distilled liquor, did not of course contain it. It was a curious fact that the fibrosis of the "hob-nail" liver, which is so often found in people who for many years indulged freely in alcohol, had been considered to be particularly associated with beer drinking—large quantities of strong beers; and, generally speaking, the stronger the beer the more silica it contained. Those were points of general interest which bore on the question.

He might say, as a result of Dr. Gye's visit here, it was hoped that the experiments which he was unable to pursue in England on account of lack of facilities, namely, the determination of the actual solubility of silica in the juices expressed from lungs and other tissues, would be carried into effect at the Government Veterinary Research Laboratories, where, of course, they had any quantity of tissue with which to carry out the work. He hoped

some light might therefore be thrown on the subject from South Africa.

One thing the chemist might consider was, how to determine soluble silica, *qua* soluble silica, without having first to convert it into SiO_2 . For instance, they got samples of water from dolomite areas, and the silica present was expressed as so much silica—say, .5 per 10,000. One would like to know how much of this was due to the dust suspended in the water and how much was soluble silica, which was dangerous. There was a problem for the chemist.

Mr. H. R. Adam said he would like to make one or two brief remarks about the hypothesis from the point of view of the chemist, because, to a chemist, it was rather a drastic statement to make that colloidal silica could be produced by the action of the fluids of the lung on even minute quartz particles in the time available. He (the speaker) did not know at all what the fluids were, but the point which did strike him in connection with the matter was that the evidence was very meagre from the chemist's point of view.

Dr. Gye apparently went from the end of the problem, and finding that colloidal silica could act as a poison when injected, practically on that basis assumed that colloidal silica could be produced in the lung. Of course he (the speaker) was not competent to discuss the matter from the physiological aspect; he simply wanted to make the point regarding the size of the particles clear if he could.

The modern conception of the colloidal state of substances was that it was chiefly a matter of particle size. If this view was correct there was no particular need to consider any process of "solution" in the lung tissue when ultramicroscopic particles were being considered; such particles were already colloidal, the dispersion medium being the lung fluids. Dr. Gye, however, evidently considered that the slightly alkaline fluid of the lung was acting chemically on the particles.

There were other points which seemed to him to be open to criticism.

The supposed analogy with the barium ion was no analogy at all, because in this case they had a reagent which was in true solution, that is, ionised. Any reaction that took place in connection with the colloidal silica would be very slow compared to such reactions as that with barium solution.

There was just one other point he would like to make. Dr. Gye mentioned that direct proof that it was possible for colloidal silica to be formed in the lung had proved to be very difficult. He could quite imagine that that was so; but it seemed to him—he was glad to hear Dr. Orenstein say it was going to be tackled—direct proof should be possible, because a silicotic lung, according to the hypothesis, should be in the process of forming colloidal silica. It ought to be possible to prove or demonstrate whether any appreciable part of the silica in the lung tissue was in the colloidal state; for example, it was quite possible to separate particles of different degrees of minute size by different grades of filter paper. In some such way would it not be possible to demonstrate whether any process of solution was taking place?

He had brought up these points rather hurriedly, but it seemed to him that the chemical evidence was insufficient on such an important question.

Mr. H. R. S. Wilkes said the paper which Dr. Orenstein had read had raised a point that was very interesting to all assayers. As an assayer, he would like to make a point. Conditions were, of course, infinitely better now, but in the old days they used to work in a far worse atmosphere, as far as quantity of dust was concerned, than usually obtained underground; yet there was not one single assayer to-day known to be suffering from silicosis, excepting in cases where it had been proved that he had worked below before he worked as an assayer. Personally, he had worked in former years in an atmosphere of dust, and yet he held a certificate that he was absolutely free from silicosis. He mentioned these points because he had always been under the impression that the sharp particles in mine dust stuck in the lung tissue and caused lesions, while the dust with which assayers had to deal was rounded by attrition in the fine crushers and the mill flow, and was consequently removed during exhalation or with the sputum. He would like that point brought out in Dr. Gye's reply.

Mr. C. J. Gray thought the Society was greatly indebted to Dr. Gye for his contribution. They were also indebted to Mr. E. Pam, who was, he understood, instrumental in getting Dr. Gye to take an interest in the matter, and to Dr. Orenstein,

who not only read the contribution, but had given an elaboration and an explanation which had made it more valuable.

There was only one question which he wished to ask. They knew that silicosis was produced in particular mining districts; other mining districts did not produce silicosis to any considerable extent. He was thinking more particularly of Kimberley. In Kimberley mining had gone on for a considerable number of years, and from personal observation he should say that the men working there breathed a considerably larger amount of dust than those on the mines on the Rand. It was, however, generally understood that little or no silicosis was produced in Kimberley. The difference must lie, he should say, in the character of the dust. The dust here on the Rand, which was supposed to produce silicosis, was pure silica or quartz dust; while at Kimberley the dust would consist mostly of magnesium silicates. If Dr. Gye's theory was correct they must assume that the dust produced from these magnesium silicates was not soluble in the lung fluids in the same way as was pure quartz dust; or, if it was soluble, that it did not produce silicosis—the solution did not carry silica into the blood or into the vessels in the same form that a solution of quartz would do. It was really a chemical question as to whether one of these complex magnesium silicates will dissolve in alkaline fluids, such as he understood existed in the lungs to the same extent as quartz itself; and, if so, whether there is any difference in the character of the silica in the solution which is formed. He thought that was a point which might be cleared up.

Mr. H. A. White thought Mr. Gray had raised a very interesting point. Of course, if they were dealing with an acid solution no doubt magnesium silicate would be much more soluble than pure silica; but if they were dealing with a slightly alkaline solution it seemed to him very much more probable that the pure silica would be very much more readily dissolved than an alkaline earth silicate. Some fourteen years ago experiments were made by him as to the effects of lime on the settlement of slime. He kept a solution of lime containing about 0.03 per cent. of CaO, about quarter its weight of slime; he kept that shaken repeatedly in a stoppered bottle, and by regularly titrating it for about three months he found

that the alkalinity steadily disappeared; so that in about thirty days half of the alkalinity had gone. This indicated that combination between the finely divided silica present in the slime and the slightly alkaline solution of lime certainly took place. Dr. Gye's paper had shed very new and valuable light upon this miners' phthisis question, and he thought that what they really ought to be devoting their attention to now was as to how they could utilise the information that was put before them. It was quite clear that their present methods of testing for the presence of silica in the air were inadequate, and it seemed to him possible that they would have to turn their attention to an optical method, especially as the film that Dr. Orenstein referred to showed up very clearly by means of strong lighting the presence of the dangerous silica in the air, whereas to the naked eye, and without that particularly powerful lighting it was not visible at all. Therefore, it seemed to him an optical method by means of very powerful illumination and possibly examination from the point of view of how much of the light that is reflected was polarised, might give them some idea of the contamination still affecting the air in our stopes. He was afraid they had been devoting their energies in the past principally to counting or weighing those coarser particles of dust, which had not been doing the mischief.

Dr. A. Mavrogordato pointed out, with regard to the solubility of silica, that when he started on this work, some eight years ago in Dr. Haldane's Laboratory, they asked themselves the same question that Dr. Gye put up: Was it the silica itself that did the mischief, or possibly, some other soluble substance that was associated with it? With a view to testing that they exposed animals to inhalation of pure precipitated silica. If they exposed animals to silica prepared in that way, in a much greater concentration than they had exposed them to the mineral dust, it disappeared from the lung at a remarkable pace; it did not stay there. Animals that had been exposed to precipitated silica and kept under observation for a similar time to animals exposed to smaller amounts of mineral silica developed no lesions at all. It was on the strength of that experiment that he came to the conclusion that silica might be soluble in the tissue juices, and that the peculiar behaviour of mineral silica by contrast with other dusts might be related to its slow

solubility in the cells. He put forward this view in a paper read before the B.M.A. in that room something over a year ago, and he entirely agreed with Dr. Gye's view that the behaviour of silica was related to its solubility, and its peculiar behaviour on the cells that took it up by contrast with other dusts was finally due to the fact that soluble silica was formed. He did not see how one could account for the disappearance of the precipitated silica apart from its solution. Except in the above series he had worked throughout with the mineral dust, and not with the colloid, and he had performed, at one time or another, many of the experiments with the mineral that had been done with the colloid in London; that was to say, he had injected suspensions of the mineral silica into the veins. He had fed silica in large quantities to animals in mineral form, when it produced no damage whatever, as far as he could make out, and, what was more, an examination of the organs showed no presence of mineral silica particles when mineral silica was fed. That was in very marked contrast to what happened when it was given by inhalation, when particles could be detected all over the body. Again, when he injected the mineral in suspension into a vein it reached all the organs, some much more than others, more especially the lungs, liver and spleen. He had drawn the conclusion that since they could find plenty of mineral silica in the liver and spleen it would produce the same effects in the liver and spleen, if it stayed there, as it produced in the lungs, and this was entirely in keeping with the results obtained by Dr. Gye with colloidal silica. He had deposited finely divided sterilised mineral silica into the peritoneal cavity and produced the same effect in the peritoneal cavity that they got in the lung. The fact that mineral silica and colloidal silica both produced the same type of action was most readily explained on the assumption that mineral silica passed into colloidal solution in the tissue juices.

As to the danger of ultra-microscopic particles, he did not think it was so important as it sounded. As he had already said, the animals which received the large doses of precipitated silica did not get any damage at all. That was one point that struck him.

The next point was some evidence they had got from the Medical Bureau. One would think if the soluble silica got all over the body in the required concentration that

then their patients would get tuberculosis all over the body, and not only in their lungs. As a matter of fact the most striking part about it was that the damage in white men was almost always confined to the lungs. If they took the native, whose tubercle was usually generalised, they would find he very rarely had *well-marked* clinical silicosis; but, on those rare occasions when he did get well-marked clinical silicosis, then the tubercle was usually confined to the lungs, and not spread about. He would expect that if the finest silica inhaled spread all over the body, one would get tubercle all over the body. There was always a certain amount of silica present in all living tissues, as Dr. Gye had pointed out, and the reaction depended on the amount present; to produce pathological effects it had to reach a certain concentration. The first thing that happened when silica inhaled was retained in the lung was an obstruction to the interchange of tissue fluids. In those obstructed areas of the lung where they had the stoppage of interchange between the tissue juices, the silica went on dissolving and was able to reach concentrations comparable to that obtained with colloid injections, and thus the dust did its damage. Supposing they did not have any obstruction which raised the local concentration, he himself doubted whether it would reach a general concentration sufficient to do damage. He thought the two factors, the solubility of the silica and the obstruction which enabled the dissolved silica to accumulate, had to be taken into consideration to account for what happened in connection with miners' phthisis.

As regards the animal tests, there was one interesting thing he could tell them about. In 1915 or 1916 Dr. Watt and his fellow workers kept rats underground exposed to much the same conditions as the men, and they were left throughout the twenty-four hours; they were not taken out at night, and were exposed to the dust after blasting. Those animals developed silicosis in about eight months. Mr. Pirow, of the Mines Department, had been keeping rats underground, repeating Dr. Watts' experiment. He had been examining the lungs of those rats for Mr. Pirow. He had examined two last week, for instance. In those two, which had been underground since January, 1921—that was to say, nearly double the time Dr. Watts' were underground—there was no evidence of the silica doing any damage, although there was

plenty of silica lying about in the lung. He thought that was rather an interesting fact and did suggest that even within the last six years the conditions had changed advantageously. They now hoped to carry out these animal tests on a larger scale. As a pathologist he had no enthusiasm for any mechanical test such as the konimetric or gravimetric. In England miners were also up against dangerous conditions which could not be detected by the senses, for instance the gases in the coal mines. What they did was to keep small animals underground, such as mice and birds. Small animals were the best test they were going to have for the hygienic condition of their mines here, and by carrying on this work of Mr. Pirow's on a larger scale, and by comparing the health of animals underground exposed to various different conditions, perhaps they would be able to get on to those places which require most attention; the way the animals' lungs behaved should help them a great deal. As regards the native, the same applied to him; it was not only tubercle and silicosis from which the natives suffered; animals exposed to the same conditions as the native, both above and below ground, might teach us where the native contracted his complaints. He might say he could not agree that the native was free from silicosis. He had not had any practical experience in examining the native for clinical silicosis, but had had a good deal of experience in examining natives' lungs. Within the last two weeks he had seen the lungs of two natives who had perfectly definite silicosis when studied *post mortem* and under the microscope. He did not know how far the figures were reliable, but neither of them had been at work here for more than three years, according to their papers. As Dr. Orenstein had pointed out, a good deal of that three years was probably not spent as a miner on the Rand. They could not compare the white miner here with the miner in Europe, Australia and America. He had usually three or four drills under his supervision, he was not behind a drill the whole of the shift; during his shift he was only spending a small proportion of the time actually behind the drill, whereas the native spent a much longer time there. He thought they had to keep their eye on the natives' lungs rather carefully. All figures were at present based on white miners' statistics. The native was much more comparable, as far as drilling went, to the drill man in England and America, in the way he was exposed to the dust. He thought

that if he developed silicosis at all he developed it earlier than did the white man, and he thought it was because he stood behind his drill for a much longer time. Native drill men are a test of drilling conditions on a large scale, and he would like to see the group of native drill men isolated and watched.

Dr. A. J. Orenstein said that while the subject was still fresh in their minds perhaps he might answer questions now rather than at the next meeting.

With regard to Mr. Adam's remarks on barium ions, Dr. Gye, in his paper, did not use barium ions as an analogy for the action of the tissue juices on silica, but merely as an illustration of the point that, in order to produce poisonous action, generally speaking, they had to have a solution, and that the barium ion was the poisonous substance, and not the chloride, in that particular instance, and the poisonous combination was brought about by the breaking down of the barium chloride into the barium ions in a true solution, just as he had used the illustration of dry salt and dry silver nitrate.

In answer to Mr. Adam's other question, with regard to the ultra-microscopic particles, perhaps it was a fault of Dr. Gye's paper that it did not make quite clear what was meant. He was quite sure he did not mean ultra-microscopic in the sense that Mr. Adam took it to be. He felt he would be quite correct in stating that the microscopic particles Dr. Gye spoke of were ultra-microscopic in the practical microscopy sense rather than in the physio-chemical sense.

There was very meagre evidence in Dr. Gye's paper of direct solution of silica into colloidal silica or silicic acid, as he called it. He (the speaker) quite agreed the paper did not cover that ground fully; it did not pretend to cover it; but, as Mr. Adam had said, it reasoned backwards. It was merely said that, by injecting colloidal silica certain lesions were produced, comparable to those produced by small particles of silica.

As to assayers being free from miners' phthisis, there were possibly many reasons for that, without taking into account Dr. Gye's theory. One explanation was that the particles were different from those encountered underground in physical property and consequent chemical action. The other one, and the one to which he thought he drew attention some time ago, was the

enormous difference in the proportions of a given amount of dust one actually inhaled under different air conditions—that was to say, the agitation from the movement of the air in a given place where dust existed would, in the long run, play an important rôle, because it would influence the amount one inhaled. If they had an enormous dust cloud in which they stood, and a strong stream of air was playing at right-angles to their nasal passages and their mouth, they would not inhale as much of the dust as if they were surrounded by a similar cloud of dust in a quiet atmosphere.

Mr. Gray's question, the speaker proceeded, was answered by Mr. White. In one case they would deal with alkaline silica compound, and if solution did take place in the lungs, it was bound to be in an alkaline medium; consequently they would not get soluble colloidal silica. The juices of the body were alkaline, and the point Mr. Gray had made rather supported the theory that free silica would be rather more dangerous than, say, a magnesium silicate.

He was particularly indebted to Mr. White for mentioning the experience he had had that water with lime in solution lost its alkalinity more rapidly in the presence of silica. He would communicate this to Dr. Gye and to the men who so kindly promised to carry on the experiments at Onderstepoort.

Dr. Mayrogordato had raised a number of very interesting points which he did not think really required further exposition, excepting that he would like to make a remark on the question of the importance of the evidence obtained by keeping animals underground. Without desiring to throw any doubt at all on the research carried out by the gentlemen who did it in 1915-16, it was always dangerous to compare microscopic pathological research carried out by one group of people with the microscopic pathological research carried out by another group of people. He thought when such experiments are conducted the greatest care must be taken that the animals be kept under exactly similar conditions, and also of the pathological diagnosis. The microscopic determination, or the assaying of the amount of disease in the various animals should be done by the same person, or persons of equal degree of competence.

With regard to natives, that natives were considered to be relatively immune to

silicosis, that was the general impression—that was to say, in a given number of natives it was supposed that not so many developed silicosis as in an equal number of European miners. A great many errors creep in. A very striking thing was, only a few days ago he had finished compiling the silicosis and tuberculosis statistics of natives throughout the whole of the Witwatersrand for 1916 to 1920, inclusive. Those were the years in which the present method of examining and compensating natives had been in operation without any modifications which would seriously affect the results. It was an extraordinary thing that in the last five years the number of pure silicosis and of silicosis with tuberculosis cases among natives on the Witwatersrand had more than doubled, and there was a particularly marked rise in the curve in the years 1919 and 1920. He was afraid it could not be put down solely to more careful examinations. He was afraid the natives were getting more silicosis than they were getting five years ago.

According to the Miners' Phthisis Medical Bureau there had been a marked decrease of silicosis among white people. Unfortunately, to those of them who had taken the trouble to read the statistics, it appears that the data was submitted in rather an incomplete and unsatisfactory manner, and the deductions drawn in the reports were not altogether such as would satisfy one that no very serious objections could be raised against them. That was one reason why he personally had always been pressing the Government at every opportune moment to have a careful statistical investigation into this silicosis question. The whole problem was enormously complicated by the fact that for the last three or four years approximately half of the men underground had been carefully selected by physical examination and, naturally, a great introduction of such people would vitiate any statistics crudely taken out. They must, as the statisticians say, weight their deductions by the error of that great number of specially selected people. He did not want them to go away with the impression that he had said the natives were free from, or immune to, silicosis, he merely said the general, prevailing opinion was that they were relatively immune, even with the increase in the last years they were still relatively immune, but that relativity in the last three years had been markedly reduced in ratio, if the figures to hand are at all correct.

The President remarked that it was a pleasure to note the renewed constructive interest which was being taken in this subject.

SYMPOSIUM: MINERS' PHTHISIS.

(Communicated.)

Dr. J. Moir: I have read Dr. Gye's lengthy contribution with considerable interest. It contains a new idea, and is therefore worthy of scientific consideration without bias; but I must confess that the impression which it leaves on me is that of a mare's nest!

There is no difficulty in conceiving that silica may circulate in solution in the blood, but there is grave difficulty in believing that crystalline silica can dissolve fast enough in body-fluids which have an alkalinity which is only $N/1,000,000$. Why did not the author test this point experimentally with $N/1,000,000$ caustic soda? I consider it is a scientific crime to write such a lengthy contribution on such evidence.

Secondly, what is the object of injecting a large dose of soluble silicic acid into an animal? Any chemist would foresee that the unstable soluble colloid would be coagulated by the salts in the blood and tissues, and that the particles of coagulum would be caught in the narrows of capillaries, etc. Why did they not inject a soluble silica mixture which was isotonic with the blood, and of the same alkalinity as the blood? They did not give their victims a fair chance. It appears they caused death in an animal by injecting a dose of silicic acid equivalent to 110 grains in a man. They do not tell us what strength of solution was used so that we could judge how foreign to the blood the mixture was, nor have they performed check experiments with other colloids. What would happen to a man who got an injection of 110 grains of colloidal ferric hydrate?

The author's theory may be correct, but his evidence does not prove it.

THE ACIDITY OF MINE WATERS.

By F. W. WATSON, B.Sc., F.I.C., and
R. A. COOPER.

(Printed in *Journal*, September, 1921.)

REPLY TO DISCUSSION.

Dr. Moir has raised a point of considerable interest in his discussion of this paper.

We refer to the problem of deciding which are the most actively corrosive compounds in our mine waters, and at what concentration a corrosive compound becomes dangerous. Dr. Moir considers that the problem of corrosion of iron and other metals underground does not wholly depend on acidity, but in part depends on the direct action of ferric sulphate (without acid) on metallic iron. It appears to us that as ferric sulphate in the concentrations usual to underground waters is ionised, the resulting $[H^+]$ ion concentration is normally the measure of the corrosive nature of the water. Aluminium sulphate appears to be almost equally as corrosive as ferric sulphate, and waters containing neither ferric sulphate nor "free" sulphuric acid may be powerfully corrosive.

In some cases at least, however, it is apparent that corrosive action is rendered more vigorous by the presence of copper sulphate which introduces the factor of electrolysis by deposition of metallic copper. Possibly also nickel and manganese sulphates may have somewhat similar effects or may act as catalysts.

The question of carrying out corrosion experiments on different kinds of iron or steel is a complicated one. In the first place practically no two pieces of metal are identical, and local segregations of impurities weaken the resistance of all common steels in varying degrees, while metal under strains due to deformation not followed by annealing has a lowered resistance to corrosion, so that it is difficult to obtain concordant results. Secondly, in closed systems the speed of flow and the pressure of the water are vital factors. As an instance of this we may quote the case of a water, from a large reservoir, with a hydron concentration of about $[H^+] = 1 \times 10^{-6}$; in other words the water was very faintly acid to Methyl Red indicator, and contained traces of aluminium and ferrous sulphates. Owing to the very large volume of water present the composition did not vary appreciably over long periods. This water was pumped for a number of years by an ordinary plunger pump, but recently an increased pump duty became necessary and a centrifugal pump of similar metal to the plunger was installed. The speed and pressure of the water were considerably increased, and the new pump and the pipe line were almost immediately destroyed, the pump impeller being reduced to a mere network.

A very small addition of milk of lime to this water rendered it innocuous under the new conditions, though the hydron concentration was only reduced to $[\text{H}^+] = 1 \times 10^{-6.5}$.

Under "open-air" conditions such as drip of acid waters on rails, pipes, etc., the question is quite different owing to the influence of the air, but in practice this difficulty is often beyond control, except by mechanical means, such as diverting the water, because it is only when water is gathered into definite waterways or sumps that chemical treatment becomes feasible.

There appears to be a misprint in Dr. Moir's contribution, the italicised words should presumably read "lime requirement." The indicator Bromothymol blue, suggested for determining this lime requirement, has been tested frequently, but we cannot see that it is in any way superior to Rosolic Acid in practice. It cannot be used as an "internal" indicator, as its colour change is often obscured by the bluish precipitate of ferrous hydrate which separates towards the end of the titration. On a porcelain plate the colour change may be more readily detected, but the use of indicators externally detracts from simplicity and is therefore not always desirable when acidity determinations are carried out in assay offices, engineers' offices, or even underground pump chambers in co-operation with the controlling laboratory.

There is very little difference between the end points of Rosolic Acid and Bromothymol Blue, the $[\text{H}^+]$ range of the two being practically identical, and they both show a first colour change at almost true neutrality, while the blue is very expensive, a consideration on some mines where indicator solutions are used with surprising rapidity.

Methyl Red is not used for acidity or lime requirement determinations in mine waters, because, as was pointed out in the original paper, it indicates only the removal of ferric iron and aluminium from solution, and therefore mine water neutral to Methyl Red may still be corrosive. This indicator is only used in the laboratory by skilled persons when investigating waters of unknown composition.

An interesting abstract covering the use of different indicators appeared in the January, 1922, *Journal of this Society*, and a further abstract explaining the meaning of hydrogen ion concentration and the use of the symbols $[\text{H}^+]$ and pH , etc., will appear in the next *Journal*.

COAL PILLAR EXTRACTION FROM TWO SEAMS WITH SURFACE EFFECTS.

By W. TAYLOR HESLOP, M.I.M.E., F.G.S.

(Printed in *Journal*, October, 1921.)

REPLY TO DISCUSSION.

I would like to thank Mr. C. J. Gray and Mr. T. N. Dewar for their expressions of appreciation. They both understand the peculiar difficulties met with in securing a total extraction of coal from two seams so close together.

Mr. J. A. Woodburn made the suggestion of working the two seams together by the long wall method. Long wall is only now beginning to receive the attention that it deserves in Natal, and under certain conditions it might be adapted for the extraction of two seams. At the Cambrian Colliery it is being very successfully employed where the two seams are further apart, i.e., up to 30 feet, where the seams are closer together than at St. George's Colliery it might also be used with advantage; but bearing in mind the thickness of the seams and the thickness of strata between I do not think any material advantage would have been secured.

Some managers have hesitated to adopt long wall because of the idea that natives would be afraid of it. In my experience natives will always follow a white man if they have confidence in him, and will take any risk that he is prepared to face.

I hoped that some of the Transvaal colliery managers would have taken up the endgels on the question of pillar extraction—or lack of it—in that Province, but in that I have been disappointed.

SOME NOTES ON THE PILGRIMS REST GOLDFIELDS

By H. C. F. BELL.

(Printed in *Journal*, November, 1921.)

REPLY TO DISCUSSION.

In replying to the discussion on my paper I wish to thank all those who contributed discussion and for their expressions of appreciation.

Referring to Professor Watermeyer's remarks about the want of continuity of value it is true that such cases as he cites

do exist, and they probably exist in every gold mining field. On the other hand the contrary condition also exists in our reefs.

I know of many instances where drive values have been low, but small cross drives have disclosed good values.

The first part of Mr. Woodburn's discussion has been answered by Mr. Diering, who, however, omitted several places where two reefs are payable in the same area.

At the New Lysbon Berlyn mine at Frankfort both the Bevits and one of the Theta reefs were payable.

At Peach Tree mine the two Theta reefs were payable in a small area, and here there was a stockwerk of very rich leaders between the reefs running for several hundred feet, and about 100ft. wide by about 30ft. thick.

In Dukes Hill mine it has recently been found that the Lower Theta reef is payable in many places underlying payable Top Theta reef.

In North Clewer mine both Theta reefs were payable in a small area.

At the Rest mine both Theta reefs are payable, and not very far away a large tonnage of payable Portuguese reef has been developed.

At the Uncle Bill mine the Bottom Theta reef and the Shale reef were payable.

Mr. Diering mentions three payable reefs in the same area at Theta mine. If a good deal of development can be done at this mine on the Portuguese reef, there would be good chances of exposing payable areas. This would then be the fourth payable reef on the same mine.

In regard to the position of the Blyde River quartzite at Sabie, I have never seen any quartzite above the locally recognised Blyde River quartzite. This quartzite is very thin at Sabie, and is easily weathered, and is therefore not often seen lying about the surface. It becomes thicker, and more weather-resisting as it goes north.

It is unsatisfactory to compare the position of the Glynns reef according to its distance above the base of the dolomites, because there is no well defined point where the dolomite ends, and in any case the distance will increase going north in conformity with the general thickening of the dolomite formation.

Mr. Woodburn speaks of the want of more correlation of the various dykes, faults, flow-sheets, etc. This is quite true. Outside the big mines, comparatively no written record is kept of information gained through prospecting and mining.

I believe this could be done very effectively through the agency of the local Mines and Claim Holders Associations. Some years ago it used to be done to a small extent, but of late years the Pilgrims Rest Association very seldom meets, and the Sabie Association confines itself chiefly to business affairs.

Mr. Diering's discussion on the Vaalhoek occurrences is interesting as he has had the opportunity of studying the latest developments. He suggests substituting the term "Thelma Series of Leaders" for the term "Thelma Reef," but it is rather a mouthful and I would suggest the term "Thelma Leaders."

It is several years since I was in the Vaalhoek mine, and I am therefore not prepared to criticize his views on the formation of these leaders until I have had another look through the mine. The Vaalhoek mine is most interesting from a geological point of view, and is worthy of a separate paper.

A special point of interest is the behaviour of the Vaalhoek dyke, which turns to a horizontal position at the base of the Thelma Leaders, and immediately overlies a thin horizontal leader. Recent development has probably supplied further information about this.

Contributions and Correspondence.

By E. M. WESTON.

In the November, 1921, number of the *Journal*, there is a note by Mr. H. Brazier on what he calls an "automatic cone classifier underflow regulator," with drawing and photo.

Mr. Brazier naturally treats of and describes this device, only in connection with the present Rand metallurgical practice. This device is, however, of the very greatest interest and value to the small worker. When a small mill is erected it is the usual practice to put in two tanks or settling pits, in which to separate the sands for cyaniding.

A native has to be kept in these pits to prevent the slime settling, by regulating the overflow, and on night shifts especially, this work is often badly done. If the sand is separated in the tanks in which it is to be cyanided, it must usually be turned right over by laboriously digging out to break up the slime lumps and to give it proper aeration. This is a tiresome and expensive

process which can often be seen in operation in Rhodesia and elsewhere. Where separate settlers are used, the sand must be dug out and transferred to the cyanide vats.

Messrs. Rowe and Gibson, of the Agnes Mine, Moodies, Barberton, were, I believe, the first to adopt what might be called an automatic discharge classifier to such conditions. Here the worst features of the practice described were in evidence. They eliminated the settlers and ran a tram track over the cyanide vats. It is better to keep this track more to one side of the vats than over the centre. Shovelling out is made easier if the vat is shallow. They placed the classifier, which can, if necessary, be any sort of a square box, as the sand makes its own cone, on a trolley. They arranged to deliver the mill pulp from the launder over every vat and lead it in turn into a square or round compartment in the centre of the classifier with a baffle plate just below the bottom to give a horizontal discharge, and to allow all air bubbles to rise in this compartment. The slimes' overflow is caught in a rim surrounding launder, which discharges into the slimes launder. By altering the lever balance the discharge can easily be kept of such a thickness that the sand stands up as a cone in the tank, while any moisture runs to waste through the filter. A native in charge watches lest any choking takes place and shovels the moist sand about the cyanide vat while it is full, when the classifier is moved to another tank. If powdered lime is available this is mixed with the sand as it is shovelled, and no lime is wasted in making the drain water alkaline. It must be remembered to jam the valve at the bottom of the classifier if the mill stops, as if sand does not remain in the bottom there will be a rush of slime and water. The same contrivance is running successfully on the Reliance Mine. The classifier is adjusted for level by placing wedges under the trolley wheels if the rail track is not quite level.

BOOK REVIEW

Handbook for Field Geologists. By C. W. Hayes. Third edition. Revised and rearranged by S. Paige. New York: John Wiley & Sons, Inc., London: Chapman & Hall, Ltd. 4½ in. by 7 in., 166 pp., 24 illustrations. Price, 13 6 net.

This book is a revision by the Geologist in Charge, Division of Geology, United

States Geological Survey, of one first issued in 1909 by Dr. Hayes, who was then Chief Geologist of that Survey. It is therefore based on the widest experience of the requirements of field geologists and contains much information and instruction in condensed form. Fourteen schedules "prepared with a view to securing system and completeness in making and recording observations" are specially valuable. Each schedule is a classified list of the points which should be noted when studying in the field that subject or class of deposit with regard to which the schedule is framed. Taking for instance the division Rock, in Schedule 11, Road Materials, we find that there are 55 main points to be observed which fall under 11 heads and 10 sub-heads. A person who used such a schedule would have his powers of systematic observation greatly stimulated, and when he came to write his report would not have vain regrets that he had forgotten to observe particular points while he had the opportunity.

The third edition does not differ greatly from its predecessors, but a brief mineralogy covering 19 pages has been added; improved methods of determining the thickness or depth below the surface of rock beds have been included; notes on use of the plane table have been revised; and revisions or additions of a line or two here and there throughout the book show that care has been taken to increase its usefulness where that has been possible.

— C. J. G.

Notices and Abstracts of Articles and Papers.

METALLURGY

THE ASSAY OF GOLD BULLION.—In the method now suggested, cupellation the principal object of which is the elimination of oxidisable or "base" metals—is omitted, and for inquartation copper is preferred to silver.

Sir Thomas K. Rose states that the loss of gold by absorption in the cupel is the only loss worthy of consideration. In practice at the Royal Mint such cupellation loss amounts on the average to 0.100 per 1,000; all other losses amounting to only 0.006 per 1,000. The cupellation loss is much greater when low-grade bullion is assayed. By the method now suggested, and using copper or silver for inquartation, there is no appreciable loss of gold, and the surcharge is always "plus" with any grade of bullion.

By this method the reverse of cupellation, care is taken to prevent as much as possible the elimination, before parting, of the constituents other than gold contained in the

samples. A weight of five grains is a convenient quantity to take. The weighed assays are each put into a separate cup of clay, without lead or any other addition than a weight of copper (or copper containing a deoxidiser, say, 0.5 per cent. of zinc), which, with the alloy present in the assay sample, will amount to, say, 2 to 2½ times the weight of the gold present. These assays are then melted and balled up in a heated silica tube under a steady, slow current of steam. Five minutes at a temperature a little above the melting-point of copper—which point is determined by a fragment of copper—is usually sufficient, but when a large percentage of zinc is present, ten minutes should be given.

An inert gas, such as nitrogen or carbon dioxide, may be used, but steam is preferable, as it is always available and is of assistance in the oxidation and removal of minute traces of certain metallic impurities which may be present in the alloy.

With an alloy of gold and silver or copper, or a triple alloy of these metals, a malleable, clean, bright bead or button is obtained; the same is also true when zinc is present, the latter metal, however, being oxidised and volatilised; the loss in weight of the bead, if the quantity of zinc is considerable, having to be made up with an equal quantity of parting copper. This loss gives fairly correctly the amount of zinc in the sample. Alloys for plate and jewellery of nine-carat fineness are now often met with, containing as much as 7 per cent. zinc. The results obtained from such alloys by cupellation are most unreliable, but by the method suggested they are quite satisfactory.

When metals other than those named are present in very minute quantities, their presence is indicated and may be recognised by the appearance of the bead. For example, with iron the bead is partly or completely sealed with black magnetic oxide. This may be chilled off without loss of gold, and the bead is then quite free from iron. Other metals give a dull, matted and tinted appearance to the bead. The following metals, if present in quantity less than 0.1 per cent., have not been found detrimental to the process—viz., nickel, cobalt, zinc, cadmium, lead, iron, tin, antimony and aluminium.

The inquarted bead is hammered and may be rolled out into a fillet without annealing. If annealing is desired (it is found to be unnecessary), this may be done under steam or coal gas. The fillet is not coiled in a spiral, but is merely doubled on itself, and is then parted and subsequently annealed in air in the usual manner.

Should antimony, aluminium or tin be present in the original alloy, they will occasion a surcharge, as is the case with cupellation. If as little as 0.2 per 1,000 of either is contained in the parted and annealed fillet, their presence is perceptible to the naked eye, for the gold is without lustre and tarnished. Tin in this quantity gives a very marked reddish tinge to the fillet. With 0.5 per 1,000, the fillet is too brittle to bear handling.

A gas muffle furnace, in which the clay muffle is replaced by five or six silica tubes, 1½ in. bore and 3 ft. long, is a suitable arrangement when a large number of samples have to be put

through quickly. Half of the length of each tube projects in front of the furnace, and into the unheated half the molten assays are drawn to set and cool. Each tube is connected at the back of the furnace with a steam generator, which is heated by the furnace itself. In front the tubes are open.

The cups used are deep and steep-sided depressions, formed in a clay stick, 9 in. long, and of semi-circular section, so as to slide within the tubes. There are ten such cups in each stick. A little powdered graphite is mixed with the clay. These clay sticks are moulded by hand, and may be used over and over again—in the writer's experience, seventy times or more—each stick costing in material a fraction of a penny. Each time they are used the cups are smoothed inside with emery-paper. When past use, the material is pounded and used over again. The silica tubes are found to last a long time—eighteen months and more, though fired for six or seven hours a day. When the heated halves show signs of decay the tubes are reversed, so doubling their life.

Since May, 1919, a weekly average of 1,500 samples of gold plate and jewellery, running from 22 carats down to 9 carats, have been tested by this method at the Assay Office, Birmingham, and checked by the results obtained with the same samples assayed by cupellation. In the course of the day frequently 1,000 such tests have to be made, in order to ascertain whether the wares from which the samples are taken are at least equal to or better than one or other the five legal standards for gold wares, viz., 22, 18, 15, 12 and 9 carats.

It is not customary to report the exact fineness of samples that are found equal to, or better than, the standard, but such as are found not of standard fineness are re-tested, and the results are then decimally reported.—A. WESTWOOD, *S.A. Engineering* (Institute of Metals), March, 1922, page 48. (A.K.)

THE FELD SCRUBBER FOR CLEANING METALLURGICAL SMOKE.—Metallurgical smoke is usually composed of the three components: solids (flue dust), fume (volatile constituents which may be condensed), and gases. The value of the recovered product may depend upon whether it be obtained wet or dry, and with the residual gases their temperature and moisture content may be determining economical factors.

The following is a classification of cleaning methods:—

- (1) Gravity (stagnation of gases, settling of dust particles in flues).
- (2) Baffling (plates to expose increased surface for lodgement of dust particles).
- (3) Filtering (layers of matting, bags, coke, slag, mineral wool).
- (4) Freezing (Gayley's method for removing moisture and dust).
- (5) Electrical (electrostatic precipitation of dust and moisture).
- (6) Tangential (gases introduced tangentially into cylinders with sufficient velocity to throw out the heavier particles of dust and moisture).
- (7) Spraying (gases caused to flow through streams of atomized water).
- (8) Centrifugal (gases pass through water atomized by rapidly revolving impellers. The

Feld scrubber belongs to this type, and combines the functions of gravity, baffling and spraying).

Much experimental work with various scrubbing processes was carried out, and the difficulty of removing zinc compounds from furnace gases is mentioned. At the temperatures existing the gases are not generally saturated with these compounds, so that the temperature has to be reduced until it represents the saturation point before the compounds will precipitate from the gas. Practically atmospheric temperature must be reached before the last traces of zinc can be removed from furnace gases.

The Feld scrubber consists of a number of separate chambers with ports or openings at the bottom of each chamber which act as passages for the ascending gas as well as overflows for the counter-current flow of scrubbing or absorbing liquid. The vertical shaft is provided in each chamber with a series of concentric frustrums of cones, which, when the shaft revolves pick up or pump the scrubbing medium which is thrown horizontally with considerable velocity through an outer perforated distributing cone, and the liquid is projected through the gas space in the form of a fine high-velocity spray, which, upon impact with the shell, is broken into a mist or fog. Intimate contact between gas and liquid is obtained, finely divided insoluble matter removed, and soluble constituents recovered. The large liquid surface exposed to the gas stream, the number of contacts, the small volume of scrubbing medium, and high concentration of effluent, freedom from internal stoppages, easy control of the apparatus and low installation and running costs are pointed out.

A 5-ft. diameter seven-section Feld scrubber will clean approximately 200,000 cubic feet of gas per hour (55.5 cubic feet per second), and will require about 20 gallons (2.675 cubic feet) of scrubbing liquor for each 1,000 cubic feet of gas cleaned. On the same basis 1.1 gallon of scrubber liquor each second will be delivered to the scrubber, the gas space of which is about 150 cubic feet, so that a unit volume of gas takes about 2.7 seconds' time to pass through the scrubber.

For each chamber or section of the scrubber the liquor is picked up by the revolving cones, dashed into spray and mist, the latter coalesced and precipitated to the bottom of the chamber only, in turn, to be picked up by the cones, and the cycle repeated in a period of about one-half second. The peripheral speed of the cones is 1,500 to 2,000 feet per minute. A calculation of the number of particles of scrubber liquor produced is given.

The effect of ionic attraction between the positively charged spray or mist particles produced in the scrubber and the negatively charged fume particles in the gas delivered to the scrubber is, since these oppositely charged particles are brought into such intimate contact, to cause the fume particles to be settled and submerged within the liquid and thus removed from the gas stream. W. F. LAYMONS, *Engineering and Mining Journal*, February 4, 1922, page 116. (A K.)

THE FUNCTION OF OIL IN FLOTATION.—In order of decreasing potential or solution tendency the potential or electromotive series is given as follows: Na, Ca, Mg, Al, Zn, Cd, Fe, Ni,

Su, Pb, Bi, Sb, As, Cu, Hg, Ag, Pt, Au.

Sodium particles that have been thoroughly coated with coal-tar or pine-tar by immersion possess for a few seconds the physical property of floatability when placed on the surface of water, the chemical reaction between the sodium and the water being retarded by the oil-film. The reaction is not retarded to the same extent with less viscous oil, such as wood-cresote, castor-oil and pine-oil.

The floating of a particle of magnesium in distilled water by the bubbles of hydrogen which condense on its surface does not happen if a 0.2 or a 0.1 per cent. solution of potassium permanganate is used, probably because the hydrogen combines with oxygen from the permanganate. Chemical action between water and magnesium particles insulated with a film of coal-tar or pine-tar is practically nil, but bubbles produced mechanically adhere to the oil-filmed particles and buoy them to the surface.

With and without oil, mechanically produced bubbles can be condensed on particles of aluminium, zinc, iron, metal, tin, copper, silver and gold immersed in distilled water at 20°C., and the particles will float, proving that under certain conditions oil is not necessary to the condensation of gases on metallic surfaces.

If the film of oxides is removed from lead particles while submerged in distilled water or oil the particles may then be floated readily, thus proving that oil is necessary in case the chemical changes taking place at the metallic surface produce a pronounced lowering of potential.

Experiments proved that using saturated copper sulphate solution and oil filmed magnesium, aluminium, zinc, iron, nickel and tin, the precipitation of copper was considerably retarded, which showed that an oil film will interfere in an ionic chemical reaction between an electrolyte and a metallic surface.

A method of estimating the lowering or raising of the potential of sulphide particles when agitated with various electrolytes is described, the bubbles produced having to conform to a set standard, and the intensity of the potential being estimated by the degree of attraction between the particles and the air-bubbles.

Pyrite particles (50 + 60 mesh) after agitation in distilled water adhered readily to a bubble 5 mm. diameter, whereas those agitated with 0.1 per cent. potassium permanganate solution did not adhere. Pyrite was found to show a pronounced change of metallic lustre with the oxidiser—an oxidiser being a salt or gas in solution that lowers the potential, a reducer one that raises the potential. The materials of the sulphides, chalcopyrite, galena, pyrite, sphalerite and stibnite when agitated in sulphuretted-hydrogen or sulphur dioxide water were equal to or greater than the potentials of the same sulphides agitated in distilled water, whereas the potentials approached zero when agitated with potassium permanganate solution. The potentials of the same sulphides did not approach zero if 0.1 per cent. wood-cresote, pine-oil or pine-tar was added to the 0.2 per cent. potassium permanganate before agitation. When the oil was added after agitation of the sulphide with the permanganate solution then the potentials of the sulphides

approached zero. These and other experiments proved, as with the members of the potential series, that an ionic chemical reaction was retarded between an oil-filmed sulphide particle and an electrolyte. Other experiments showed that after the potentials of the sulphides were lowered to apparent zero by agitating with an oxidiser, they were restored by agitating with a reducer; metallic lustre were likewise changed and restored.

Oil, as used in the flotation process has three distinct physical properties: (1) By lowering the surface tension of the water it permits the formation of a permanent bubble at the air-solution interface; (2) the adhesive force between a metallic surface and oil is greater than the adhesive force between a metallic surface and water; (3) the potential tends to remain constant on an oil-filmed metallic sulphidic surface provided the surface is subject to chemical changes. Apart from simplicity and economy the necessity for oil depends on the lowering of the potential—the rapidity and degree of oxidation. Sulphides have been floated successfully in electrolytes to which reducers have been added without the use of oil. Potassium permanganate, as used in selective flotation, increases the difference between the potentials of two or more different sulphides. In all probability the theoretical law of condensation of gases on metallic surfaces is as follows: The members of the potential series condense gases on their surfaces directly as the intensity of their potentials, but inversely as the power to lower their potentials, and the same should apply to sulphides. As with metals, high potentials on sulphides are lowered readily.—D. W. LEEKE and R. H. JARVIS, *Mining and Scientific Press*, February 18, 1922, pages 223-226. (A.K.)

Mining

INVESTIGATING STRATA BY PERCUSSION WAVES.
—In British patent 20,225 of 1920 (174,095), Dr. J. W. Evans, F.R.S., of the Imperial College of Science and Technology, and W. B. Whitney describe a new method of investigating the interior of the earth's crust with the object of determining the position and nature of hidden strata without borings and thus assisting in the exploration for coal, petroleum, metalliferous deposits, etc. The method is based on the moulding and modifying influence which strata or surfaces of discontinuity in the earth's crust exert upon sound waves or like pressure vibrations which pass through them or are reflected by them.

According to a previous method of this nature, in order to investigate the interior of the earth, a sound is emitted from a suitable source and its echo or return or the sound which arrives at a distant point is observed by a receiving mechanism, and the time elapsing between the emission of the sound and the reception of the echo or between the emission of the sound and its arrival at the distant point is also measured, the sound producer and the receiver being electrically interconnected for this purpose. From the observation obtained conclusions are drawn as to the probable nature of the medium which has been traversed by the wave. The method to which the present invention relates, as distinguished

from the older method, is characterised in that the sound waves, after having been modified by the medium under examination, are received simultaneously or approximately so at a number (at least two and preferably three or more) of receiving stations placed at a distance from the transmitting station. The distance apart of the generating and receiving stations will generally be considerable, say, one mile, but may be greater or less, depending upon the nature of the earth's crust which is under examination. The receiving apparatus are preferably so placed that they lie approximately on lines radiating from the generating apparatus as centre and between 90° and 120° apart. Records of the vibrations at the generating station and at the various receiving stations are obtained, and a comparison of these records enables the observer to distinguish between the different reflections and ascertain the time intervals between them, even when they are so close together as to form composite waves. Owing to the different velocities in different media and the differences in reflection, refraction and absorption, the nature of the vibrations recorded and the time intervals between them will enable the probable nature and position of the media under examination to be determined.

For generating the waves several means may be employed, such as vibrations generated by means of sound, explosives, blows struck by hand, or mechanical means. For receiving the vibrations the following instruments, for example, may be employed according to circumstances: Microphone, carbon, liquid, or jet; telephone receiver, in combination if necessary with automatic make-and-break device such as a commutator. The following are examples of recording apparatus that may be used: Einthoven string galvanometer fitted with automatic photographic recording device; apparatus based on the piezo-electric properties of quartz, stethoscope, oscillograph, etc., in combination with automatic recording devices.

The inventors describe a specially devised receiving apparatus, which comprises essentially a casing that can be firmly embedded in the ground, a mass resiliently supported or suspended within said casing and one or more pins or the like inserted in an electrical circuit between the mass and a microphone or other apparatus whereby the relative movement between the casing and the mass, which occurs when the portion of the stratum in which the casing is fixed, and therefore the casing itself is set in motion by the passage of a vibration from the generator while the mass owing to its inertia tends to remain fixed in space, may be detected. Instead of pins a hemispherical elastic body may be employed. The apparatus may be constructed in several forms.—The *Mining Magazine*, March, 1922, pages 190, 191. (C.J.G.)

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CONTENTS.

	Page.
Frontispiece—The late Lt.-Col. C. B. Saner	237
PROCEEDINGS AT 26TH ANNUAL GENERAL MEETING	239
Minutes	239
Annual Report...	239-245
Election of Officers and Council	246
New Members	247
Exhibition and Demonstration of Devices of Practical Advantage	248
Gold Precipitation by Zinc Dust and in conjunction with the De-aeration of Solution at Modderfontein "B," by S. Newton and L. L. Fewster	249-258
The Correlation of Metallurgical Statistics, by H. A. White. Reply to Discussion	258
The Combustion of South African Coals in Boiler Furnaces, by E. P. Reim, B.Sc. Reply to Discussion	258-260
Obituary—Lt.-Col. C. B. Saner	260-261
Book Reviews	261-262
NOTICES AND ABSTRACTS.	
Chemistry	263
Mining	264
CHANGES OF ADDRESS	264

NOTICE.

*The next Ordinary General Meeting will be held in the Scientific and Technical Club, 100, Fox Street, Johannesburg (between Rissik and Loveday Streets), on **Saturday, 16th Sept., 1922, at 7.45 p.m.***

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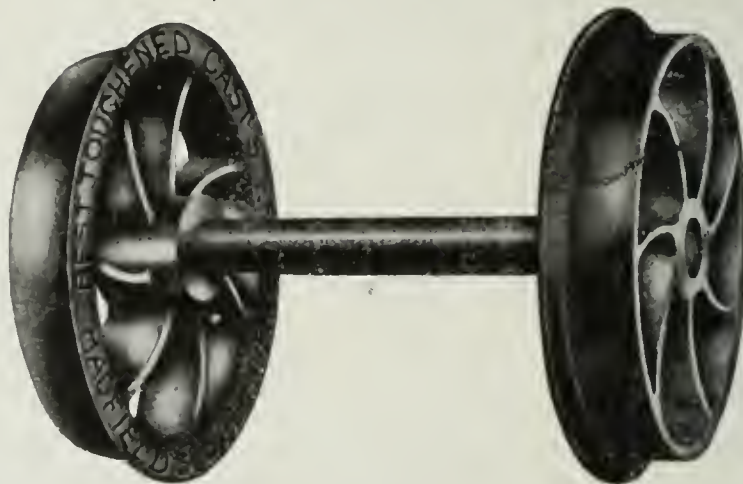
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Vol. XXII.

JUNE, 1922.

No. 12.

Proceedings

AT

26th Annual General Meeting,
24th June, 1922.

The Twenty-Sixth Annual General Meeting of the Society was held in the Assembly Hall, Scientific and Technical Club, 100, Fox Street, Johannesburg, on Saturday, 24th June, 1922, at 8 p.m., Mr. F. Wartenweiler (President) in the chair. There were also present:—

28 Members: Prof. G. A. Watermeyer, Messrs. F. W. Watson, C. J. Gray, J. R. Thurlow, H. R. Adam, H. S. Meyer, J. E. Thomas, John Watson, H. A. White, Prof. J. A. Wilkinson, J. A. Woodburn (Members of Council), W. Beaver, H. D. Bell, J. M. Dixon, L. L. Fewster, W. S. Gordon, Jas. Gray, A. Hebbard, J. Henderson, W. Martin, S. Newton, F. D. Phillips, H. Pirow, T. Probert, J. J. R. Smythe, J. M. Thorburn, J. T. Triggs, and H. R. S. Wilke.

4 Associates: J. A. Boyd, C. E. Deakin, W. Russell, and A. A. Wood.

1 Visitor and H. A. G. Jeffrey (Secretary).

MINUTES

The Minutes of the Ordinary General Meeting, held on the 22nd April, 1922, as reported in the April *Journal*, were confirmed.

The President said they were unable to confirm the Minutes of the May Meeting, as the *Journal* had not yet been published. However, they expected it to be in their hands early next week.

The Secretary read the Annual Report as follows:—

ANNUAL REPORT OF COUNCIL.

The following is the report submitted by your Council on the work of the Society during the past year:—

Accounts.—From the Revenue and Expenditure Account now before you it will be seen that the result of the activities of the Society for the year shows a nett profit of £84 1s. 10d. This may be considered highly satisfactory when compared with the corresponding figures for the years 1920 and 1921, when losses were made of £115 14s. 2d. and £104 7s. 11d. respectively. The improvement in the position of the Society is very largely due to a favourable printing contract having been entered into, with the result that the *Journal*, the publication of which involved a loss of £184 last year, has been produced at a profit of £161, that is, a saving of £345. Comparing the items of the expenditure side of the account with that of the last year, economies are shown to have been effected in Charges and Printing and Stationery, this last account having to bear the cost last year of printing the revised Constitution and Rules of the Society.

As was anticipated, the transfer of the Society's office to the building of the Scientific and Technical Club has involved an increased rental expenditure. Salaries are at practically the same figure, while it is expected that the small debit shown under the head of Transactions will shortly be recovered from Sales. Your Council has donated £25 towards the maintenance of the Seymour Memorial Library, and has also provided prizes for Evening Class Students at the Witwatersrand University.

On the Revenue side of the account the decrease of £39 in the aggregate

	June, 1899	June, 1902	June, 1903	June, 1904	June, 1905	June, 1906	June, 1907	June, 1908	June, 1909	June, 1910	June, 1911	June, 1912	June, 1913	June, 1914	June, 1915	June, 1916	June, 1917	June, 1918	June, 1919	June, 1920	June, 1921	June, 1922
Hon. Members ...	14	9	13	18	18	16	17	18	21	22	20	23	25	25	26	26	25	23	22	21	24	24
Life Members ...	1	1	1	2	3	4	7	7	8	9	9	9	10	10	10	9	9	9	9	10	10	10
Members ...	281	291	441	639	680	680	683	618	630	731	711	733	618	550	481	463	451	469	463	340	363	370
Associates ...	238	243	281	338	321	314	342	357	342	402	380	442	396	351	287	272	263	270	270	178	166	165
Students ...	—	—	—	4	8	4	7	18	20	60	57	22	21	15	2	3	5	2	2	6	—	1
	534	544	736	1,001	1,030	1,018	1,056	1,018	1,021	1,224	1,177	1,229	1,070	951	806	773	756	773	766	555	563	570

subscriptions received is due to the reduced number of arrears recovered. Entrance fees from new members are slightly less. As previously stated the *Journal* account shows a profit of £161; the nett revenue from the advertisements is £15 higher, while the cost of printing ordinary *Journal* matter has been reduced by £330. The sum of £11 has been recovered in respect of the March 1921 Exhibition, and £6 has been realised from the sale of sundries in connection with the removal to the Society's present offices.

Turning to the Balance Sheet it will be observed that while the cash balances are lower there is a more than corresponding reduction in the amount due to creditors. The amount due to the Society under Sundry Debtors is in respect of current advertisements and *Journals* ordered by firms of repute.

Membership.—Thirty-seven new members have been elected during the year, and your Council has admitted twenty-five associates and one student.

Eight Members and five Associates have resigned, while your Council has to record with extreme regret the deaths of the following:—Alexander Heymann, J. Keough, J. Martin, H. W. Pridgeon, Major L. A. E. Swinney, and James West.

As in previous years, the names of certain members and associates in arrear with their subscriptions and with whom the Society has entirely lost touch have been struck off the roll.

Papers and Journals.—The original papers read before the Society and the contributions to discussion thereon have continued to be of the high standard which has always characterised this branch of the Society's activities. The cheaper printing facilities already referred to have enabled your Council to enlarge that section of the *Journal* devoted to *Notices and Abstracts*, and to this end seven members have been appointed to assist the Editorial Committee in selecting abstracts from current literature.

It has occasionally happened that there has been some delay in the publication of the *Journal*, necessitating the holding over of confirmation of Minutes of Meetings, but this slight inconvenience is more than compensated by the financial consideration.

The following original papers have been published during the year:—

July, 1921:—

"A Resume of Standard Methods in Sampling, Analysis and Classification of Coal," by A. Trevor Williams.

August, 1921:—

"Symposium: Miners' Phthisis." Contribution by W. Allen.

September, 1921:—

"The Acidity of Mine Waters," by F. W. Watson and R. A. Cooper.

"Symposium: Miners' Phthisis." Contributions by J. A. Woodburn and John Watson.

October, 1921:—

"The President's Address," by F. Wartenweiler.

"Coal Pillar Extraction from Two Seams and Surface Effects," by W. T. Heslop.

November, 1921:—

"Some Notes on the Pilgrims Rest Gold Fields," by H. C. F. Bell.

December, 1921:—

"The Correlation of Metallurgical Statistics," by H. A. White.

January, 1922:—

"The Combustion of South African Coals in Boiler Furnaces," by E. P. Reim.

February, 1922:—

"Features of Metallurgy of a Refractory Gold Ore," by F. Wartenweiler.

"Notes on the Manipulation of Osmiridium Concentrates," by R. A. Cooper.

April, 1922:—

"The Development of the Blast Furnace," by J. Henderson.

May, 1922:—

"Notes on Osmiridium," by J. R. Thurlow.

Technical Examination of Lubricating Oil and Grease, by F. W. Watson and H. D. Bell.

"Symposium: Miners' Phthisis." Contributions by W. E. Gye, A. J. Orenstein, A. Mavrogordato, H. R. Adam, H. R. S. Wilkes, C. J. Gray, H. A. White, and James Moir.

June, 1922:—

"Gold Precipitation by Zinc Dust and in Conjunction with the Denaturation of Solution at Medderfontein 'B,'" by S. Newton and L. I. Fewster.

Research Endowment Fund—This fund has benefited during the year by one small donation and now stands at £412 15s. 10d.

Your Council has awarded Gold Medals to the following gentlemen for the best papers read before the Society during recent years:

Chemistry: Dr. James Moir.

Metallurgy: Dr. W. A. Caldecott and Mr. H. A. White.

Mining: Mr. John Innes.

A full report of the presentation of medals was published in the October *Journal*. Although these, the first awards made since the inception of the fund, are for work done during past years, your Council has recommended that future awards shall be for current work only.

The Exhibition.—The usual Exhibition was not held as your Council had under consideration a scheme for promoting a Mining and Industrial Exhibition towards the end of the year on a scale much larger than any previously attempted.

Unfortunately the industrial upheaval and revolution during the first three months of 1922 compelled the abandonment of the idea.

Annual Dinner.—In consequence of the want of assurance of support and bearing in mind the loss sustained on the last occasion, your Council again reluctantly decided not to hold this function. It is to be hoped that improved conditions will justify a revival of the Annual Dinner during the coming year.

Excursions.—By the courtesy of the Director of the South African Institute for Medical Research members of the Society paid a visit to the Institute on the 3rd December last, a report of which appeared in the January *Journal*.

A visit was also made to the works of the South African Products Manufacturing Company, Ltd., at Germiston on the 17th of this month, which proved highly interesting and instructive.

Invitations to visit the works of the Union Steel Corporation and the Brick and Tile Works at Vereeniging, the Hume Pipe Company's Works at Germiston, the Rand Refinery and the Rand Carbide Works, have been received, and the necessary arrangements will no doubt be completed by the incoming Council.

Associated Scientific and Technical Societies of South Africa.—In last year's report it was stated that the scheme for "Closer Working and Joint Housing" had been realised in the acquisition of the completely equipped and furnished premises of the Scientific and Technical Club. Since then

the activities of the Associated Societies have been greatly increased and it has been found necessary to provide a Maintenance Fund independent of any possible revenue which may be derived from the Club. With this object the Associated Societies have assessed each Constituent Society for the year 1922 in an amount based on its membership. Particulars of this assessment, and the report of your Council of its action in regard thereto, were placed before you at the Ordinary General Meeting held here on the 18th February last, and duly published in the February *Journal*. This Society has been assessed for the year 1922 in the sum of £363 6s., subject to rebate in respect of duplication of membership, of which the first quarterly instalment, £90-16s. 6d., has been paid from members' contributions. The second payment of a like amount falls due on the 1st of July next, and at present the sum of £16 16s. only is available to meet it. It is therefore a matter of urgent necessity that those members and associates who have not yet paid their contributions should do so without delay.

War Memorial.—To perpetuate the memory of members of the Society who lost their lives in the Great War your Council has decided to have the names of those members inscribed on a bronze tablet which will be placed in this Hall. Professor G. E. Pearse (Professor of Architecture at the Witwatersrand University) has very kindly prepared a design, a copy of which has this night been hung in the place which the tablet will presently occupy.

Council.—Nine meetings of the Council have been held during the year as well as several Committee Meetings. The attendance at the Council Meetings averaged 12.1 for eighteen members as compared with the same average last year, when, under the old Constitution, Past Presidents were *ex officio* members of Council, and the full strength of the Council was thirty-two members.

The following were the individual attendances:—

F. Wartenweiler	7 ¹
J. Chilton (Past President)	— ¹
C. J. Gray	9
G. A. Watermeyer	6 ¹
F. W. Watson	6 ²
J. R. Thurlow	8 ¹
H. R. Adam	5 ¹
E. H. Johnson	3 ¹

J. H. Johnson	6 ²
A. King	8 ¹
H. S. Meyer	7
A. J. Orenstein	8 ¹
J. E. Thomas	6 ¹
J. Watson	9
A. Whitby	6
H. A. White	5 ¹
J. A. Wilkinson	2 ³
J. A. Woodburn	8

Leave of absence granted for ¹ one meeting, ² two meetings, ³ four meetings.

The Council desires to place on record its appreciation of the services rendered by the Hon. Auditors and the Hon. Legal Advisers.

The President: In moving the adoption of the Annual Report, I take the opportunity to draw your attention to various features and to bring forward views which have been impressed upon me during my presidential year. It will be noticed in a study of the balance sheet and the statement of revenue and expenditure that we are in the happy position of recording an actual gain for the year under review. When it is boiled down it will be found that the chief factor is the decreased cost of printing, which is always one of the largest items of expenditure. Considering the state of depression generally and the increase in fixed charges, such as rent, the financial year may be regarded as a satisfactory one.

With regard to the Research Endowment Fund, perhaps members will receive an impression that it is considerable and that more might be done with it. Suggestions are welcomed and opportunities will no doubt arise to encourage some concrete scientific research, which will expand the usefulness of the fund and fulfil its original purpose.

In respect of membership we have more than held our own and have secured an addition. Although our membership is the largest of the Technical Societies in South Africa we cannot let that suffice, but must continue to build up on the excellent foundation of wide interests which we possess. It should be remembered that the Chemical, Metallurgical, and Mining Society of South Africa was the pioneer in this part of South Africa and that from the beginning its membership consisted of men of many professions, especially those allied to the mining industry, which was then in its infancy.

While the technical qualifications required for membership have not been based

entirely on scientific and technical learning. the Society was fortunate in having as members all the broad gauge men of the time, men of constructive genius who developed this most wonderful mining field in its various departments. And to-day we can still claim as members men of the highest technical attainments in the fields of chemistry, metallurgy, and mining, and we have expanded by adding members who are authorities in applied chemical industries, coal products, iron smelting, and also in the medical aspect of the industries in which we are interested. Lastly we have retained, and continue to add members who are scientists in the art of finance, an avocation which, although it is not called technical, yet requires as much constructive thought based on scientific principles and is as exacting, or more so, as those pursuits called strictly professional.

It is to be regretted that so few of the young men are joining. No doubt the tendency of these times is more for amusement and less for scientific thinking. If any serious attention is given by the younger men to science it is more apt to be given to the science of socialism. The abstract principles expounded in such books as "Science and Revolution," "The Class Struggle," and "The Right to be Lazy" are preferred as reading matter to studies in abstract science or the *Journal* of our Society.

Our propaganda which teaches principles based on fact and sanity and encourages men to achieve success and happiness by useful and creative work is too laborious and constructive for those who expect to rise by destruction and a general levelling. Let us trust that this is only a passing phase and that interest will revive in science and technical progress among the younger men and that new discoveries and fields of industry will enlarge their mental horizon and also their scope for advancement.

In considering the *Journal* it is perhaps not always realised by the local section that one-third of our members reside outside the Transvaal, and many are scattered over the various countries of the globe. To these the *Journal* is the only means of retaining contact with us, and we appreciate their interest all the more. It is for such distant members and for those who reside within reach, but do not find it convenient to attend meetings, that the *Journal* is the principal medium, and for this reason it is of paramount importance.

It has been the Council's object and endeavour to supplement our original papers by means of abstracts to keep pace with recorded current scientific literature and progress. Abstracts, if comprehensive and systematic in following the developments in fields we cover, can be most useful.

The papers read before the Society have on the whole maintained the standard set in the past. The Council has received several complimentary letters in this respect. Several new members have presented useful papers, and perhaps more of the younger members would come forward were not some of our veterans so severe in their critiques. While not wishing to discourage healthful criticism a more dignified tone in its exercise would often encourage members to present us with an account of original work performed.

In the course of the year the attendance at Council Meetings has been all that could be desired. The attendance at General Monthly Meetings, however, leaves much room for improvement. It has also been difficult to obtain papers for reading. I have naturally given these matters some thought and propose to submit to the incoming Council a few suggestions concerning organisation for their consideration.

The year has been abnormal in our local history, and the times have not been conducive for the encouragement of that interest in the affairs of the Society which might otherwise be expected. I have a conviction, however, that with our wide interests and progressive membership its useful career will continue.

In conclusion I have pleasure in acknowledging the faithful services of our competent Secretary. My colleagues in the Council have given the Society valuable service. Our Hon. Treasurer, Mr. J. R. Thurlow, continues to wield his financial pen with deftness, and even finds time to contribute to the *Journal*. I wish to express my sincere appreciation to all.

Gentlemen, I have pleasure in moving the adoption of the Annual Report.

Prof. G. A. Watermeyer had much pleasure in seconding the adoption of the Annual Report.

The adoption of the Annual Report and Statement of Accounts was passed unanimously.

FORM A.—MEMBERS.



Founded March 1894
Incorporated May 1897

SCIENTIFIC AND TECHNICAL CLUB,

100, FOX STREET, JOHANNESBURG.

Elected 19...

Advised 19...

Entered 19...

No.....

P.O. Box 1183. Telephone No. 1404.

Telegraphic Address: "PERSPICAX."

We, the undersigned MEMBERS OF THE CHEMICAL, METALLURGICAL AND MINING SOCIETY OF SOUTH AFRICA, hereby recommend—

Candidate's name in full

as a fit and proper person to become a Member of the above Society.

For names only of } (Proposer)
Members recommending }
and the candidate. } (Seconder)

And I, the said Candidate for Membership, hereby declare that if elected I will do my best to support the Society and will observe its Rules and Bye-laws.

Signature of Candidate

Address to which the
Candidate wishes the
Society's publications
to be sent, and which
is to be entered in the
Society's Register

Profession or Business
Occupation

Date

EXTRACTS FROM CONSTITUTION AND BYE-LAWS.

The objects of the Society are—

- (a) To advance Technical and Metallurgical Chemistry and the Science and Practice of Mining.
- (b) To cultivate all branches of pure Chemistry.
- (c) To extend the knowledge and practical application of improvements and discoveries in matters bearing on the Chemical, Metallurgical and Mining professions and to afford Members opportunities for interchange of ideas on Chemistry, Metallurgy and Mining.
- (d) To do all things which may be desirable for the attainment of the above described objects, or any of them.

Members. Every candidate for admission as a Member shall be proposed and seconded by two Members in accordance with the form in annexure "A" hereto. The proposal shall be submitted to the Council, and, if approved, the candidate shall stand for election at the Ordinary General Meeting next following. The election shall be by ballot at that Meeting, one adverse vote in ten to exclude. Notice of the names of the candidates for election shall be sent to all Members prior to the Meeting.

Every candidate shall on his election or admittance be duly notified of the fact by the Secretary, and no election shall be confirmed until the candidate shall have paid the fees due to the Society, on election or admittance.

The Entrance Fee for Members and for Associates and Students who may be subsequently elected to Membership shall be One Guinea, payable on election.

Each Member shall pay an annual subscription of Two Guineas; each Associate shall pay in annual subscription of One and a Half Guineas; and each Student shall pay an annual subscription of Half a Guinea. All subscriptions shall become due on the 1st day of July in each year, and shall be payable in advance.

Should any Member, Associate, or Student be elected on or after the 1st January of any year, his subscription for the remainder of the current financial year shall be one-half the annual subscription.

The Council shall have power to strike the names of Members, Associates and Students, whose subscriptions are in arrear for two years from off the Roll of the Society, or to deal with such defaulters as it may see fit.

Members, Associates and Students whose subscriptions for the current year remain unpaid after the 1st day of October may be denied the privilege of the Society pending payment of the same. The Council may, on the report of a Sub-Committee appointed by them for the purpose, remit the subscription of any Member, Associate or Student for any period as it may deem desirable, if good and sufficient reasons be advanced by any Member, Associate or Student.

Members, Associates and Students may at any time resign from the Society by giving written notice to the Secretary, and on payment of all liabilities to the Society then existing on their part, such resignation shall be accepted by the Council.

FORM A.—MEMBERS.



Founded March 1894
Incorporated May 1907

SCIENTIFIC AND TECHNICAL CLUB,
100, FOX STREET, JOHANNESBURG.

Elected 19...

Advised 19...

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Candidate's name in full

as a fit and proper person to become a Member of the above Society.

For names only of } (Proposer)
Members recommending }
the Candidate. } (Second)

And I, the said Candidate for Membership, hereby declare that if elected I will do my best to support the Society and will observe its Rules and Bye-laws.

Signature of Candidate

Address to which the
Candidate wishes the
Society's publications
to be sent, and which
is to be entered in the
Society's Register.

Post office or Business
Correspondence.

Date

EXTRACTS FROM CONSTITUTION AND BYE-LAWS.

The objects of the Society are—

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- To cultivate all branches of pure Chemistry.
- To extend the knowledge and practical application of improvements and discoveries in matters bearing on the Chemical, Metallurgical and Mining professions and to afford Members opportunities for interchange of ideas on Chemistry, Metallurgy and Mining.
- To do all things which may be desirable for the attainment of the above described objects, or any of them.

Members.—Every candidate for admission as a Member shall be proposed and seconded by two Members in accordance with the form to be used. A hereto The proposal shall be submitted to the Council, and, if required the candidate shall stand for election at the Ordinary General Meeting next following. The election shall be by ballot at that Meeting, one adverse vote in ten to exclude. Notice of the names of the candidates for election shall be sent to all Members prior to the Meeting.

Every candidate shall on his election or admittance be duly notified of the fact by the Secretary, and no election shall be confirmed until the candidate shall have paid the fees due to the Society, on election or admittance.

The Entrance Fee for Members and for Associates and Students who may be subsequently elected to Membership shall be One Guinea, payable on election.

Each Member shall pay an annual subscription of Two guineas, each Associate shall pay in annual subscription of One and a Half guineas, and each Student shall pay an annual subscription of Half a Guinea. All subscriptions shall become due on the 1st day of July in each year, and shall be payable in advance.

Should any Member, Associate, or Student be elected on or after the 1st January of any year, his subscription for the remainder of the current financial year shall be one-half the annual subscription.

The Council shall have power to strike the names of Members, Associates and Students, whose subscriptions are in arrear for two years from off the Roll of the Society, or to deal with such defaulters as it may see fit.

Members, Associates and Students whose subscriptions for the current year remain unpaid after the 1st day of October may be deemed the possessors of the Society's pending payment of the same. The Council may, on the report of a Subcommittee appointed for that purpose, remit the subscription of any Member, Associate or Student for any period as it may deem desirable, if good and sufficient cause be advanced by any Member, Associate or Student.

Members, Associates and Students may at any time resign from the Society by giving written notice to the Secretary, and on payment of all balances due to the Society then existing on their part, such resignation shall be accepted by the Council.

FORM B.—ASSOCIATES.



Founded March 1894
Incorporated May 1907

SCIENTIFIC AND TECHNICAL CLUB,
100, FOX STREET, JOHANNESBURG.

Elected 19...
Advised 19...
Entered 19...
No.....

P.O. Box 1183. Telephone No. 1404.

Telegraphic Address: "PERSPICAX."

I hereby apply for admission as an Associate of THE CHEMICAL, METALLURGICAL AND MINING SOCIETY OF SOUTH AFRICA, and declare that if admitted, I will do my best to support the Society, and will observe its Rules and Bye-Laws.

Signature of Applicant.....

Applicant's name in full.....

Address to be
Registered

Profession or Business
Occupation.

Date

EXTRACTS FROM CONSTITUTION AND BYE-LAWS.

The objects of the Society are:—

- To advance Technical and Metallurgical Chemistry and the Science and Practice of Mining.
- To cultivate all branches of pure Chemistry.
- To extend the knowledge and practical application of improvements and discoveries in matters bearing on the Chemical, Metallurgical and Mining professions and to afford Members opportunities for interchange of ideas on Chemistry, Metallurgy and Mining.
- To do all things which may be desirable for the attainment of the above described objects, or any of them.

Associates.—Applications for Associateship shall be made in the form provided in annexure "B" hereto. Associates shall be admitted by the Council. Should an Associate desire to become a Member of the Society, such Associate shall be proposed, approved and elected in the manner provided for in Bye-law 2. Associates shall have all the privileges of Members, with the exception of holding office and voting.

Every candidate shall on his election, or admittance, be duly notified of the fact by the Secretary, and no election shall be confirmed until the candidate shall have paid the fees due to the Society, on election or admittance.

The Entrance Fee for Members and for Associates and Students who may be subsequently elected to Membership, shall be One Guinea, payable on election.

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The Council shall have power to strike the names of Members, Associates and Students, whose subscriptions are in arrear for two years, from off the Roll of the Society, or to deal with such defaulters as in its discretion it sees fit.

Members, Associates and Students whose subscriptions for the current year remain unpaid after the 1st day of October may be denied the privileges of the Society pending payment of the same. The Council may, on the report of a Sub-Committee appointed by them for the purpose, remit the subscription of any Member, Associate or Student for such period as it may deem desirable, if good and sufficient reason be advanced by any Member, Associate or Student.

Members, Associates and Students may at any time resign from the Society by giving written notice to the Secretary, and on payment of all liabilities to the Society then existing on their part, such resignations shall be accepted by the Council.

	£	s.	d.	£	s.	d.	1920-21.	£	s.	d.	ASSETS.	£	s.	d.	1921-22.	£	s.	d.
LIABILITIES																		
STOCKY CREDITORS				161	15	3					By Cash							
STOCKY ALMOHAR LAMANY				25	0	0					Standard Bank of South Africa, Ltd., Johannesburg	26	6	1				
ASSOCIATED SECURITIES AND TRADING SOCIETIES OF SOUTH AFRICA											Standard Bank of South Africa, Ltd., London	9	15	3				
PROVIDENT JOINT HOUSING SOCIETY				1	1	0					On hand	2	1	5				
SUBSCRIPTIONS PAVING ASSOCIATION											Standard Bank of South Africa, Ltd.							
MEDICAL ASSOCIATES				2	2	0					On Fixed Deposit with Interest accrued	105	10	10				
REVENUE EXCESS AND EXPENDITURE ACCOUNT				3	13	6					Savings Bank Account.							
Balance at 31st May 1921																		
Balance at 31st May 1922				350	13	1					By Cash							
STOCKY ALMOHAR LAMANY											Standard Bank of South Africa, Ltd., Johannesburg	26	6	1				
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REVENUE EXCESS AND EXPENDITURE ACCOUNT				3	13	6					Savings Bank Account.							
Balance at 31st May 1921																		
Balance at 31st May 1922				350	13	1					By Cash							
STOCKY ALMOHAR LAMANY											Standard Bank of South Africa, Ltd., Johannesburg	26	6	1				
ASSOCIATED SECURITIES AND TRADING SOCIETIES OF SOUTH AFRICA											Standard Bank of South Africa, Ltd., London	9	15	3				
PROVIDENT JOINT HOUSING SOCIETY				1	1	0					On hand	2	1	5				
SUBSCRIPTIONS PAVING ASSOCIATION											Standard Bank of South Africa, Ltd.							
MEDICAL ASSOCIATES				2	2	0					On Fixed Deposit with Interest accrued	105	10	10				
REVENUE EXCESS AND EXPENDITURE ACCOUNT				3	13	6					Savings Bank Account.							
Balance at 31st May 1921																		
Balance at 31st May 1922				350	13	1					By Cash							
STOCKY ALMOHAR LAMANY											Standard Bank of South Africa, Ltd., Johannesburg	26	6	1				
ASSOCIATED SECURITIES AND TRADING SOCIETIES OF SOUTH AFRICA											Standard Bank of South Africa, Ltd., London	9	15	3				
PROVIDENT JOINT HOUSING SOCIETY				1	1	0					On hand	2	1	5				
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ASSOCIATED SECURITIES AND TRADING SOCIETIES OF SOUTH AFRICA											Standard Bank of South Africa, Ltd., London	9	15	3				
PROVIDENT JOINT HOUSING SOCIETY				1	1	0					On hand	2	1	5				
SUBSCRIPTIONS PAVING ASSOCIATION																		

We have examined the above Balance Sheet and accompanying Revenue and Expenditure Account together with the Books and Vouchers of the Society for the year ended 31st May, 1922, and have obtained all the information and explanations which have required. In our opinion such Balance Sheet is properly drawn up so as to show a true and correct view of the state of affairs of the Society at the 31st May, 1922, according to the best of our information and the explanations given to us, and as shown by the Books of the Society.

JOHN W. STUBBS, 10th June 1922. (Signed) ALEX. ALKEN and GARTHER, Auditors.

(Signed) J. R. TURLOW,
Hon. Treasurer

(Signed) H. C. JEFFREYS,
Secretary.

STANLEY ALLEN and CAROL J. LUDERS.

Dr.	RESEARCH ENDOWMENT FUND. REVENUE AND EXPENDITURE ACCOUNT for the Year ended 31st May, 1922.		Cr.
	1921-22.	1921-22.	
	£ s. d.	£ s. d.	
1921-22.		1921-22.	
	£ s. d.	£ s. d.	£ s. d.

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BALANCE SHEET as at 31st May, 1922.				1921-22.				1921-22.				1921-22.			
				£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
LIABILITIES.															
To Sundry Creditors				161	15	3	161	15	3	161	15	3	161	15	3
" SEYMOUR MEMORIAL LIBRARY				25	0	0	25	0	0	25	0	0	25	0	0
" ASSOCIATED SCIENTIFIC AND TECHNICAL SOCIETIES OF SOUTH AFRICA				1	1	0	1	1	0	1	1	0	1	1	0
Donation Joint Housing Scheme.															
" SUBSCRIPTIONS PAID IN ADVANCE—				2	2	0	2	2	0	2	2	0	2	2	0
Members				3	13	6	3	13	6	3	13	6	3	13	6
Associates															
" REVENUE ENDOWMENT FUND				5	15	6	5	15	6	5	15	6	5	15	6
" REVENUE AND EXPENDITURE				412	15	10	412	15	10	412	15	10	412	15	10
Account—															
Balance at 31st May, 1921...				350	13	1	350	13	1	350	13	1	350	13	1
Balance old Mining Exhibition Fund Transferred															
Add Excess of Revenue over Expenditure for the year ending 31st May, 1922 ...				84	12	10	84	12	10	84	12	10	84	12	10
Deduct Excess Expenditure over Revenue.				435	5	11	435	5	11	435	5	11	435	5	11
104 7 11)															
350 13 1															
£1114 1 0				£1041	13	6	£1114	1	0	£1041	13	6	£1114	1	0

We have examined the above Balance Sheet and accompanying Revenue and Expenditure Account together with the Books and Vouchers of the Society for the year ended 31st May, 1922, and have obtained all the information and explanations we have required. In our opinion such Balance Sheet is properly drawn up so as to exhibit a true and correct view of the state of affairs of the Society at the 31st May, 1922, according to the best of our information and the explanations given to us, and as shown by the Books of the Society.

(Signed) ALEX. AIKEN and CARTER, Auditors.

(Signed) J. R. THURLOW,
Hon. Treasurer

(Signed) H. A. G. JEFFREYS,
Secretary.

RESEARCH ENDOWMENT FUND.—REVENUE AND EXPENDITURE ACCOUNT for the Year ended 31st May, 1922.										Cr.	
Dr.		1920-21.		1921-22.		1920-21.		1921-22.			
£	s. d.	£	s. d.	£	s. d.	£	s. d.	£	s. d.	£	s. d.
0	17 6	To EXPENSES		7	5 0	386	5 0	By DONATION			
		Collins Bros. for four Gold Medals for year 1921.									
		.. BALANCE, being excess of Revenue over Expenditure for the year		17	15 0			9	13 4	.. INTEREST RECEIVED	
395	0 10										15 0 0

However, that was not the fault of the scrutineers. He thanked them most heartily for carrying out their duties, which had been less onerous this year than before.

Mr. S. Newton, on behalf of the Scrutineers, wished to thank members for the very kind remarks which had been made. He could assure them he looked forward to seeing the pile of ballot envelopes bigger in the future than it was now. It would be a work of love to them if they could only extend their labours two or three hours longer.

Mr. C. J. Gray proposed a hearty vote of thanks to the Honorary Auditors, Messrs. Alex. Aiken and Carter, and to the Honorary Legal Advisers, Messrs. Van Hulssteyn, Feltham & Ford, of the Society, and proposed their re-election.

Mr. H. A. White had much pleasure in seconding the vote of thanks.

The vote of thanks and re-election were agreed to unanimously.

NEW MEMBERS.

The ballot was taken for the election of new members, and the following were declared unanimously elected. —

BURN, N. W., American Cyanamid Co., 511, Fifth Avenue, New York City, U.S.A.;
Technicologist.

DE SMIDT, R. A. H. F., Modder Deep Levels, Ltd., Benoni; Dust Inspector.

HEBBARD, H. J., Witwatersrand G.M. Co., Ltd.; Knight Mine Captain.

Mr. H. R. Adam wished to thank Mr. Wartenweiler for the very excellent work which he had done as President during the past year. They all knew the tremendous amount of work he had put into his year of office. With regard to the remarks which the President had made a moment or two ago, he thought they would all appreciate his thoughts very much in the future.

Mr. Jas. Gray said he had much pleasure in seconding the vote of thanks to the President for the manner he had worked in the interests of the Society during the past year. He thought Mr. Wartenweiler had set a very high standard in the Chair, but he was satisfied that Professor Watermeyer would maintain it.

The President said he would like to draw the attention of members to the fact that Professor Wilkinson, one of their Past

Presidents, and one who had served for eighteen years continuously on the Council, including the Presidency, was about to retire from the Council. He thought they should take note of it, and pass a vote of thanks.

Mr. Watermeyer, in seconding, said he thought it ought to be a vote of censure. Professor Wilkinson had done very well, but there was no reason why he should not do a bit better. (Laughter.)

Prof. J. A. Wilkinson thanked them very much indeed for that unexpected pleasure. The reason he was dropping from the Council of the Society at the moment was because he had now a good deal of extra work to do in addition to his own duties, in that new laboratories for the Chemical Department were being built at Milner Park, and, in addition, his was one of the heaviest departments in the University. He had felt in past years that he had not been able to give that attention to the Society he ought to have given, and for that reason he felt he ought to make way.

There was another reason, and attention had been drawn to it that night; it was this — he had often felt, when gentlemen in the Chair had been asking the younger members of the Society to come forward, that there had been a plethora of the older members who stood in their way. He had felt it was only the due of the younger members that they should be allowed to take up the reins of office and see what the administrative work of a council like theirs was like. Therefore he thought the people who had served a long time ought to make way for such. For these two reasons he had stood down this year. He would like to tell them that his interest in the Society would not cease with his departure from the Council. He felt sure that the Council they had elected that night, under the guidance of Professor Watermeyer, would go forward, and that the new Council would uphold its traditions.

It was indeed a wrench to disengage himself from the Council after all those long years of service, which he would probably feel more as the days went by, in that he was not in the councils of those who were running the Society.

Shortly they were to have a Memorial Tablet on the wall for all those members who had laid down their lives during the late war, and he hoped when that tablet

came that most of the members of the Society would roll up and support the Council in doing their duty to those brave men, whose memory would be thus perpetuated.

He wished the new Council every possible success in the coming year; and, in doing that, of course, it was to wish the Society and the members of the Society every possible success.

Looking back on the years he had served on the Council, he did not think he had ever served with a body of men where there had been greater harmony, and with whom it had been such a real pleasure to work.

The President announced that the index of the *Journal* for the years 1920-21 would be in the hands of the printers some time in July.

Mr. Jas. Gray asked whether the Society was printing a list of members. He thought it was about seven or eight years since this had been done. Now that printing expenses were down he thought it only right that they should have a revised list in order that they might know who were members of the Society.

The President, in reply, said he was very glad the matter had been brought up. It would be referred to the Council.

EXHIBITION AND DEMONSTRATION OF DEVICES, ETC., OF PRACTICAL ADVANTAGE.

DEVICE FOR UTILISING WORN TUBE MILL BARS.

Mr. J. R. Thurlow: On the table are models of a device for utilising worn tube-mill bars as mortar box and chute liners. The bars are cut to size with bevelled ends and held in place by the turned edge of the container. The latter is made from 3/16th inch mild steel plate, in three sections to fit the interior of the mortar box—or as many as desired for chute-lining purposes. In the case of mortar boxes it is found in practice that it is seldom necessary to disturb the container once it is in position, the worn bars being readily removed and new ones inserted with the container in position. If, however, it is desired, the containers can be removed and replaced by duplicates as in the case of ordinary liners, the worn

sections being sent to the blacksmith for renewal of bars. The cost of a set of containers for mortar boxes is estimated at £5; except they meet with accidental damage they last indefinitely, the worn bars only being replaced. The price of the bars depends on circumstances. Usually they are obtainable as scrap at a nominal figure, the cost of the cutting is not a serious item, and where tried the scheme has resulted in appreciable saving in cost of lining mortar boxes.

As regards the life, it is difficult to give a definite figure owing to the variation of the incidence of the wear and, to some extent, the variation of quality in the bars. Under fair wear and tear conditions containers lined with bars from local iron works show a life of two-thirds that of the best manganese liners.

The device has been originated by Messrs. Butler and McCarthy, of the Knight Central Mine.

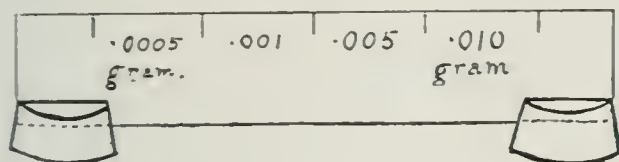
Mr. H. A. White moved a hearty vote of thanks to Mr. Thurlow for the explanation of his interesting device. He thought it required to be explained that perhaps the idea of using those bars to save the lives of mortar boxes was not entirely new, because they had had a description of two devices already given before the Society; one he believed was by Mr. Dickson, and the other by Mr. Neill. But the point he noticed about this was, the new device contained in the container itself, which rendered these things much more useful, but he might say, in connection with the other devices, descriptions of which had already been published, they had sometimes gone out of use, because it had been found very difficult to retain the bars in the right position. The device before them now seemed to have got over that difficulty, and therefore represented considerable improvement. He had much pleasure in moving a vote of thanks to Mr. Thurlow.

RIDER STAND FOR ASSAY BALANCE.

Mr. John Watson: This little device can be made by any handy person in a short time, from a piece of clean white cardboard, two sections of cork, and a few drops of seccotine or glue. It may be regarded as an addition to the weight-box, which usually has only one space for riders.

A mine assayer, who has to weigh the beads (parted or not) at the end of his assay process, does probably 95% of such weighing with rider weights.

The stand shown this evening (sketch herewith) will carry four different riders: half milligram, 1 milligram, 5 milligrams,



and 10 milligrams, which will be found sufficient for most purposes. The riders sit astride of the cardboard, each in its proper marked position, and can be lifted by the forceps, gripping, flat-wise, over the looped head.

This little stand can be kept inside the balance-case, and it will be found that the wear and tear of the riders is reduced to a minimum. The chief advantage is the ease of changing the rider from stand to balance-beam and *vice-versa*. Having got a set of four riders of proved accuracy, the one in use will be on the balance-beam, or rider-lifter, the other three on their respective positions on the stand.

Mr. Jas. Gray in proposing a vote of thanks to Mr. Watson, said he also had a grievance, viz., that it had taken him eighteen years to tell them about the device. (Laughter.) He would like to tell Mr. Watson that he could easily get over the bone or steel forceps' difficulty by using a camel hair brush, which was the proper thing to use.

GOLD PRECIPITATION BY ZINC DUST AND IN CONJUNCTION WITH THE DE-AERATION OF SOLUTION AT MODDERFONTEIN "B."

By S. NEWTON and L. L. FEWSTER, A.R.S.M.

The precipitation of gold from cyanide solutions by zinc dust at Modder "B" dates from 1911 when milling operations first commenced. This paper deals with two periods, viz., that prior to the introduction of de-aeration of solution and the period subsequent to this.

Arrangement and Design of Plant.—The precipitation plant consists of the usual solution clarifier, solution sumps, zinc feeder, two triplex Gould pumps, one small centrifugal pump, and two Merrill precipitation presses.

The layout of the plant is simple and direct, the chief fault in design being that the Gould pumps are on ground level, whereas the "steady head" or general solution supply sump is below ground level, thus making a flooded pump suction impossible without structural alterations. This point, apparently overlooked in original design, is of considerable importance, and had to be rectified when the Crowe method of de-aeration of solution by vacuum was installed in September, 1921.

The sump directly connected with the precipitation plant is distinct from sand and sludge treatment sumps and is—

One direct solution settlement tank, 45' x 7', cone bottom.

Three gravity sand clarifiers, 45' x 6', flat bottom.

One steadyhead or general solution supply sump, 40' x 4', flat bottom.

One filtrate or press effluent intermediate sump, 25' x 5', flat bottom.

One filtrate or precipitated solution storage sump, 50' x 8', flat bottom.

One strong solution sump, 20' x 8', flat bottom.

The two original Gould pumps had plungers of 7" and 8" diameter, strokes of 8" and 10", and capacities of 50 tons and 60 tons per hour respectively. The smaller pump has since been replaced by a larger one of the same type with 8" plungers and 12" stroke which at the present speed of 44 crank shaft revs. per minute has a capacity of 88 tons per hour.

Zinc Feeder.—The original zinc feeder intended for use with zinc dust was the belt type, the control of the feed being by means of cone pulleys driving pawl gears, the zinc to be fed being spread along the belt. This type of feeder had been tried previously at New Modder G.M., and discarded on account of irregular feeding owing to the belt slipping. The spiral or worm feed was therefore installed at Modder B. It is simple and consists of a hopper containing

the zinc, through the bottom of which a long screw operates—the speed of the screw controlling the feed, theoretically. Owing to the peculiar “packing” properties of zinc dust, affected considerably by humidity, this method of feeding had to be discarded.

The next zinc dust feeder to be used was made on the mine and was quite novel, as far as the authors are aware. This Modder B. feeder was designed and made in 1914 by Mr. Paterson, the cyanide fitter, and has been used satisfactorily until the installation of the de-aeration process in September, 1921. It allowed of the finest adjustment required at the time, viz., about 150lbs. per 24 hours, and gave an almost continuous feed. Its description is as follows:—

The cone has a bracket carrying a white iron pinion and shaft which revolves on two bearings on the base plate. Above the pinion is a white iron bar which takes all the weight of the cone hopper containing zinc dust. When the press pump starts it causes the feeder pinion to revolve at about 14 r.p.m., resulting in a vibrating and up and down movement of the hopper, which prevents any tendency to choking of the regulator cock at the bottom of the hopper. This feeder has practically only one wearing part, the white iron bar, which requires changing about three times a year.

Until October, 1921, the zinc from the feeder had been washed down a 3" pipe by a small amount of solution from the Gould pump delivery, together with a continuous drip of lead nitrate solution and 10 tons per hour of strong solution (.05% KCN), supplied by a small centrifugal pump used to maintain strength of general supply of solution for precipitation.

We have now reverted to the belt type of feeder with our own simple modifications which have resulted in an absolutely controllable feed. This is obtained by using a leather belt, for carrying the zinc dust, the edges of which are punched with 3" holes, pitched to mesh over sprockets on the head and tail pulleys, the belt being driven by chain and gears. There is thus no slipping of the zinc feed belt or intermittent motion due to pawl action.

With the reversion to this method of feeding came the introduction of the cone fitted with float and plug attachment, arranged so as to maintain a practically constant solution level in the cone and forming an effective seal which prevents air from being drawn with the zinc emulsion into the pump. Inserted in this cone is a vortex

mixer which draws down and wets the zinc particles which otherwise would have a tendency to float on the surface of the solution. In all types used the zinc feeder has been driven from the pinion shaft of the Gould pumps.

Precipitation Presses.—There are two Merrill precipitation presses originally of 40 units each, but since extended to 46 units each. A unit consists of a standard 52" triangular hollow frame and double-sided drain plate (constructed on similar lines to the more familiar Johnson filter press), and the feed pipes are so arranged that the solution and precipitant enter from the bottom of each hollow frame. The solids, gradually accumulating in the frames, are kept in constant agitation and the best efficiency in zinc dust precipitation obtained. The solid frame or filter plate has two top discharges. The plates are covered with a double thickness of 12 ounce cotton duck, which have a life of about four months.

Experience has shown that one of the main essentials of good precipitation is a perfectly clear solution. Previously the various sands solutions and slimes solutions were precipitated separately, but recently only one solution or one combination of solutions has been precipitated. The whole of the “loading” solution obtained from the Butters plant together with the first portion of the “wash solution” 20 mins. or 30 mins. of the total wash of 60 mins. is delivered to the settling tank, and thence through the three clarifiers placed in parallel to the “steady head.” Into the “steady head” is also run the first 30/36 hours of the first leaching from the sands treatment tanks. The attached diagram gives an idea of the solution cycle. (See Flow Plan.)

The pumping system is arranged so that any desired solution from the sumps or steady head can be pumped at will, the pump delivery being connected by two pipes, direct to the precipitation presses. Two gauges, one near the pump and the other between the presses indicate pressure conditions.

When commencing a fresh cycle of precipitation, zinc dust is fed in at the rate of 500 lbs. the first day, 350 lbs. the second day, 200 lbs. the third day, and then about 150 lbs. for each of the remaining days of the run.

The gold cyanide solution together with the zinc precipitant is pumped into the precipitation presses where the solution must pass through a uniform filtering layer of

The Associated Scientific & Technical Societies of South Africa



FILM EXHIBITIONS.

By arrangement with the African Films Trust and local firms in possession of suitable films, a monthly exhibition of Travel, Industrial and Technical films will be given in the Scientific and Technical Club, 100 Fox Street, Johannesburg.

These exhibitions will take place at 8 p.m. on the fourth Saturday of each month, commencing July, 1922.

Admission will be free to Members, and friends accompanying Members.

CLUB DANCES.

Monthly Dances will be held in the Scientific and Technical Club on the first Saturday in each month, commencing August, 1922, open to Members and their friends.

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Royal School of Mines Frecheville Research Fellowships



The Imperial College of Science and Technology, South Kensington, London, S.W.7, with which the Royal School of Mines is incorporated, is offering two Research Fellowships of £300 a year each, tenable for one year and possibly renewable for a second year, to aid in carrying out any investigation or research connected with Mining, Mining Geology, Metallurgy or the Technology of Oil, which in the opinion of the Selection Committee is of sufficient use or promise.

Applicants, who may be Associates of the Royal School of Mines or others, and preferably men with some practical experience, if resident in South Africa, should apply in writing to the Secretary of the Chemical, Metallurgical and Mining Society of South Africa, Johannesburg (from whom further particulars may be obtained), before 1st September, 1922, giving the nature of the proposed investigation, qualifications for the work, and references.

It is anticipated that the Committee will make the awards by the end of November, so that the Fellowships and work may begin on 1st January, 1923. Holders will be expected to devote their whole time to the work, which may be conducted at the Imperial College, or in special circumstances elsewhere at the discretion of the Committee.

fine grained precipitant, thus ensuring contact between each metal bearing molecule and the precipitant, and leaving behind in the press the precipitated metals and the unconsumed zinc dust.

The effluent from the press or "filtrate" passes to an intermediate sump from where it is pumped to the Butters plant as "wash solution" or to the sands plant for "last washes." Drip samples are taken from the pump suction column prior to the entry of the precipitant for "head values" and similar samples are taken from the filtrates. Two-hourly samples of the filtrates are taken and tested colorimetrically. Should precipitation "go off" slightly (anything over .04 dwt. tail) filtrate samples are tested more frequently until the cause is located and remedied.

The most common troubles with precipitation are shortage of zinc feed and low cyanide strength, although the cause of unsatisfactory precipitation at times has been extremely difficult to locate.

Clean-up.—When the consumption of zinc was in the neighbourhood of 166 lbs. or zinc per ton milled there were normally two clean ups per month, but during the period of experimental work or investigation clean ups have been irregular in number, the pressure and pump duty determining the date of the clean-up. Prior to opening the press for clean-up, air is blown through to displace as much moisture as possible. A shallow tray on wheels is placed beneath the press and the closing plate of the press withdrawn. The accumulated cake of precipitated metals and surplus zinc, etc., is removed from the hollow frame and cloth by means of scrapers. The top cloth is subsequently removed, folded up, and placed in a locker until such times as the cloths are washed, either by hot water or treated with hydrochloric acid. After examination, they are either passed for a further period of usefulness or condemned, burnt and smelted. The under cloths are used as top cloths as required and replaced by new ones.

When the zinc dust process was first commenced at Modder B. the precipitate from the presses was acid treated, briquetted, scrubbed, and cupelled, but this method not being a success it was discontinued in favour of acid treatment, calcining and pot smelting, which in turn gave way to acid treatment, Taseener furnace smelting and cupelling. At the present time the precipitate is smelted in the Taseener furnace without acid treatment.

Details of Operation.—Even previous to the adoption of de-aeration the efficiency of the process depended to a great extent upon the elimination of the air contact with the solution after the addition of the zinc dust. The quality of the zinc dust employed as precipitant is very important, some supplies of zinc dust having been found to be useless as efficient precipitant. The zinc dust, which should be free from oxide, is passed through a 90 mesh sieve to remove any large particles of foreign matter. Cyanide and alkalinity strengths require careful control, the solution being kept to at least .017% KCN, and about .02% CaO.

The reducing power of solutions when it passes beyond certain limits affects precipitation, and its source is to be found in the mill water circuit which is made up from underground or mine water. Control of reducing power is maintained by testing the water with N/10 potassium permanganate and adding the requisite quantity of chloride of lime or sodium hypochlorite, which is produced on the mine at a small cost by the electrolysis of brine.

It had been the custom at Modder B. until about eighteen months ago to have a constant drip of lead nitrate solution (24 lbs. per shift) entering the circuit along with the zinc feed. When the drip of lead nitrate was discontinued and the lead nitrate solution added to the circuit via the clarifiers a very marked reduction in zinc consumption was quickly obtained. Whereas previously the consumption of zinc dust had been about 16 lbs. per ton milled or .17 lbs. per ton of solution precipitated, it fell to 10 lbs. per ton milled or .12 lbs. per ton of solution precipitated. This is apparently explained by the possibility of some of the particles of zinc becoming so heavily coated with metallic lead that they were unable to precipitate any gold from the cyanide solution. If you introduce the human factor, or neglect, in preparation of the lead nitrate solution used as a drip, it is conceivable that precipitation would be considerably affected at times by the greatly variant strength of lead nitrate solution.

Efficiency and Capacity.—The compactness and neat appearance of the precipitation plant are the first points to attract one's attention, the space occupied by the presses being only a fraction of that required by zinc boxes precipitating the same amount of solution per day. The arrangement of the plant is such that all operations are under

ZINC DUST PROCESS PRECIPITATION RECORD AT MODDER B MINE.

INDEX.	Sept. 1920	March 1921	August 1921	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 18	No. 19	No. 20	No. 21	No. 22
Period of Run From ...	26/8/20	10/3/21	11/8/21	24/9/21	10/10/21	14/10/21	17/10/21	22/10/21	28/10/21	13/2/22	27/3/22	17/4/22	24/4/22	1/5/22
Do. do. To ...	12/9/20	25/3/21	25/8/21	9/10/21	14/10/21	17/10/21	21/10/21	27/10/21	4/11/21	25/3/22	16/1/22	23/4/22	30/4/22	22/5/22
No. of voluntary stoppages ...	Nil	9	Nil	3	3	3	2	1	6	27	15	2	3	3
No. of compulsory stoppages ...	1	Nil	1	1	Nil	Nil	1	Nil	Nil	1	Nil	Nil	Nil	Nil
Total hours stoppage ...	2 hrs.	2 hrs.	30 min.	1-10	1 hr.	1-10	5 hrs.	30 min.	3-30	1	6-7	1-6	1-2	1-22
Actual running time (days) ...	17-875	15-416	14-875	15-118	3-75	2-805	4-416	5-854	7-354	13-5	14-708	5-75	5-916	20-083
Tons sol. pptd. per hour max. ...	68	66	69	88	69	70	70	76	76	72	75	74	78	78
Do. do. min. ...	56	50	66	52	67	49	65	72	70	62	70	70	67	67
Do. do. average ...	62	60	68	73	68	66	68	74	73	68	73	73	72	74
Do. do. per 24 hours ...	1500	1500	1718	1758	1643	1630	1642	1783	1750	1628	1760	1745	1737	1771
Do. do. per filter leaf p 24 hrs.	33	33	37-3	38-2	35-7	35-4	35-7	38-8	38-0	35-4	38	38	38	38
Do. do. run total ...	26329	23060	24417	26596	6161	4556	7253	10440	12874	21987	25887	10036	10278	35564
Average per cent. KCN ...	-018	-015	-019	-025	-025	-025	-025	-019	-020	-017	-02	-022	-025	-023
Do. do. CaO ...	-030	-029	-024	-033	-031	-032	-030	-025	-025	-017	-016	-020	-027	-026
Lbs. Pb(NO ₃) ₂ added per day	24	21	21	24	24	24	24	24	24	24	24	24	24	24
Value head sol. dwts. p ton max.	—	4-30	4-50	6-8	7-7	7-7	6-1	5-4	7-7	6-1	5-9	5-9	5-9	7-2
Do. do. min.	—	3-20	3-10	3-1	4-8	4-4	5-0	4-2	4-0	3-2	3-1	3-5	4-4	3-5
Do. do. aver.	2-60	3-88	4-02	5-21	5-95	5-86	5-66	4-92	5-54	4-39	4-63	4-55	4-84	5-30
Value tails do. do. max.	-05	-08	-06	-04	-03	-03	-04	-03	-04	-07	-06	-04	-05	-22
Do. do. min.	-02	-02	-02	-01	-01	-01	-01	-01	-01	-01	-01	-02	-02	-02
Do. do. aver.	-03	-037	-04	-016	-016	-016	-03	-018	-018	-027	-03	-02	-026	-035
Recovered per day aver. F.G. ozs.	193-62	288-79	327-19	456-91	488-80	472-00	462-63	437-64	483-26	355-18	405-09	397-39	418-69	463-68
Do. per run do.	3460	4452	4867	6929	1833	1324	2043	2562	355-4	4795	5958	2285	2477	9312
Zinc Fed lbs. per ton milled ...	-161	-102	-122	-058	-058	-058	-058	-058	-061	-08	-08	-06	-06	-06
Do. do. solution pptd	-173	-123	-126	-069	-072	-082	-074	-063	-063	-080	-056	-064	-063	-032
Do. per ozs. F.G. Recovered...	1-34	-634	-611	-267	-240	-280	-262	-257	-231	-367	-243	-284	-262	-237
Added filtering sodium *C.K.S.	—	—	-611	-267	-240	-280	-262	-257	-231	-367	-243	-284	-262	-237
Ozs. F.G. per lb. gold shine ...	-735	1-392	1-599	3-367	2-243	2-177	2-108	2-275	2-817	2-390	2-630	2-096	2-257	2-413

* K = Kieselguhr.

The first three columns show precipitation without solution de-aeration.

Beginning with Index No. 1, the solution is de-aerated.

control. More uniform and efficient precipitation is obtained due to the fact that a fresh surface of precipitant is being constantly exposed to the solution, whereas in the zinc shaving precipitation the zinc surfaces become insulated at times by a deposit of lime and zinc salts, necessitating frequent dressings of the boxes, which have the effect of

mechanically destroying a certain amount of useful zinc.

Owing to the extremely fine subdivision of the zinc dust only a very short time of contact between the zinc and the gold bearing solution is required to give almost complete precipitation as evidenced by the following tabulation:—

	Low Feed, Test No. 1, Dwt. per ton.	Low Feed, Test No. 2, Dwts. per ton.	10 lbs. Zinc Flush, Taken immediately after adding Zinc, Test No. 3, Dwts. per ton.
Cock No. 1, dist. 4ft. from zinc inlet	5.50	4.96	3.39
Cock No. 2, dist. 20ft. from zinc inlet	4.87	4.86	1.90
Cock No. 3, dist. 60ft. from zinc inlet	4.65	—	—
Cock No. 4, dist. 100ft. from zinc inlet	4.95	4.82	1.07
Cock No. 5, dist. 200ft. from zinc inlet	4.80	4.83	0.58
Filtrate	.02	.02	.02
Head Value	6.05	5.37	5.37

The effect of a large excess of zinc on precipitation in the pump column will be noted; also the rapidity and completeness of precipitation in the press itself.

The clean-up involves little handling of rich precipitates compared with the cumbersome and messy operation of a zinc box clean-up which of necessity is more frequent owing to the demands of efficient precipitation. It is simpler and quicker, and permits of the conversion into bullion of all precipitated gold, thus avoiding the "carry over" of the zinc shaving clean-up.

The "carry over" on a large cyanide plant would possibly be about 3,000 ozs. F.G., which at £4 10s. per ounce would represent a loss of £675 per annum at 5% interest. Losses due to handling and theft are minimized, as during the interval between clean-ups there is practically no point at which theft is possible as any interference with the press which contains all the precipitated precious metal would be immediately observed. One very marked feature of this process is the absence of white precipitate.

The capacity of the precipitation process is best indicated by reference to the accompanying tabulation.

INTRODUCTION OF 'CROWE METHOD' OF VACUUM DE-AERATION AND ITS EFFECT

This process is the most recent development in improvements of methods for precipitating gold in cyanide solution, and is applicable to both zinc shaving and zinc dust precipitation.

It was first installed in the United States. Subsequently the Transvaal Chamber of Mines conducted an investigation into its

efficiency and practicability at the City Deep, Ltd., where zinc shavings are used as the precipitant. As a result of these local trials plants have been installed at various mines on the Witwatersrand, both in connection with zinc dust and with shavings.

Vacuum de-aeration was placed in commission at Modder B. in September, 1921, and careful records have been kept of the operations since that date, as are shown to a certain degree by the graphic illustrations and the tabulations attached. Whilst in the old process the exclusion of air from the solution containing the zinc dust precipitant is practically complete, the elimination of the dissolved air or oxygen is made possible by the de-aeration method.

Cyanide solutions going to precipitation under ordinary conditions are more or less saturated with air absorbed during agitation in slimes treatment, in sands treatment, and in open pumps. The Crowe method removes the air by passing the solution through a vacuum receiver immediately prior to the addition of the zinc dust precipitant.

The attached flow plan will serve to illustrate the addition to the precipitation equipment as now converted for the application of vacuum de-aeration. These additions form a complete and independent unit in themselves, making it possible to isolate the de-aeration portion of the equipment and run on previous practice, as would be necessary, for instance, if the vacuum pump broke down for any length of time.

The above additions consist of a solution "booster" pump, vacuum pump, vacuum receiver, and necessary connections, valves, etc. The booster pump is a 6in. Sulzer with 40ft. head, which forces the gold bearing

cyanide solution from the steadyhead to the top solution inlet of the vacuum receiver.

The vacuum receiver is a cylindrical iron tank 12ft. high and 8ft. diameter, placed at a height of approximately 35ft. above the valve chests of the Gould pump, thereby maintaining a flooded suction of the Gould pump, this height being necessary to overcome the effect of the vacuum in the receiver. From an efficiency point of view this flooded suction is imperative in order to prevent ingress of air through pump glands.

The upper portion of the vacuum receiver is filled with wooden grating through which the solution from the booster pump passes. While not actually atomised the solution exposes sufficient surface to the effect of the vacuum that its dissolved oxygen content is reduced from about 6 mgm. to 0.5 mgm. per litre. The lower portion of the receiver acts as a small storage tank for the Gould pump, the supply to the receiver being controlled by a butterfly valve in the booster pump delivery column actuated by a crank rod connecting the valve with a ball float inside the receiver.

A gauge glass indicates the height of the solution in the receiver and a pressure gauge on the booster pump column immediately below the butterfly valve shows the pressure acting against the pump.

The vacuum is maintained by a Worthington feather valve water cooled vacuum pump connected by lin. piping to the top of the vacuum receiver. The gauge usually shows 22in. of vacuum.

The de-aerated solution passes from the bottom of the receiver to the Gould pump suction, receiving on its way the zinc dust precipitant which is fed as described previously.

The vacuum pump and receiver have a capacity of 3,000 tons per 24 hours, but a duty of 2,050 tons suffices at present.

The operation of the process is continuous and practically no operative attention is required beyond adjusting the solution duty and the keen observation of details as for the old process. The routine cycle of operations is simple; the gold, cyanide, and alkalinity values have to be controlled as previously, and samples are taken and gold tests performed. Oxygen tests are also carried out as part of the routine.

After clean-up the presses are re-dressed, closed up, the rate of flow of solution fixed and zinc is fed in at the rate of 40 lbs. in the

first 45 mins., 40 lbs. in the next 75 mins., and 40 lbs. in the next 120 minutes.

The filtrate values are usually down to .04 dwts in from one to two hours when the zinc feed is cut down to 4 lbs. per hour.

The filtrate samples are continually being tested colorimetrically until good precipitation is established.

Since the introduction of the Crowe method the acid treatment of the zinc gold slime, as mentioned before, has been discontinued and direct Tavener furnace smelting of the precipitate resorted to on account of the decreased consumption of zinc and increased value of precipitate and smaller amount of precipitate to be treated. Should, however, the zinc consumption be still further reduced it will possibly mean that pot smelting of the slime will be advisable.

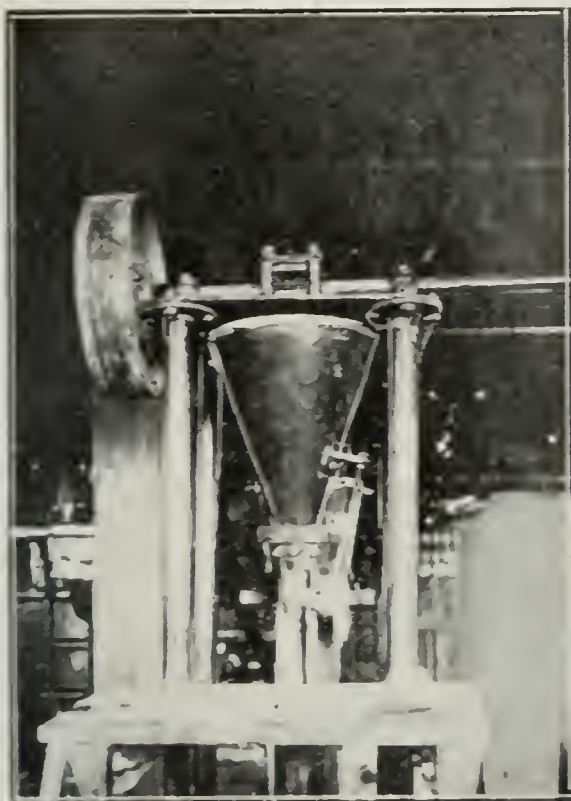
As the full precipitation plant is the only experimental plant possessed by this mine it will be obvious to all practical members that investigations proceed at a painfully slow rate when clean-ups are carried out only twice per month, and the most important features from the manager's point of view is the "call" and the filtrate values.

From the results of one or two recent determinations it has been found that the zinc gold slime from the clean-up now contains about 40% moisture and the dried slime is reducible in weight by about 45% by treatment with sulphuric acid.

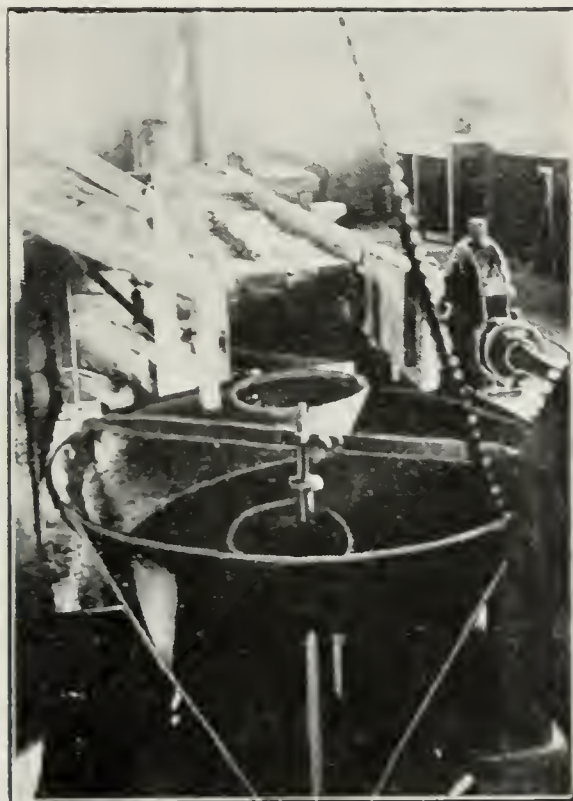
The chief practical disadvantage, if it may be so termed, of de-aeration applied to zinc dust precipitation from the purely practical side is due to the smaller amount of precipitant used and consequent higher grade of precipitate, which results in a more slimy and less permeable cake in the press. Experiments have been carried out employing various materials as added filtering mediums, such as ground coke, sawdust, and Kieselguhr in order to obtain a more porous cake in the press. So far Kieselguhr appears to be the most satisfactory added filtrant. The effect of a sufficient amount of this aid to filtration is shown in the graphs attached.

The graphs and tabulation supply a record of operations and results over continuous periods and represent the everyday practice of the process.

Our thanks are due to Mr. C. L. Butlin, Manager, and Mr. K. L. Graham, Consulting Metallurgist, for permission to publish these notes. Also to Mr. Barry, the Refinery Superintendent, for valuable assistance and photographs.



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No. 3 Cake in position in Precipitation Filter.



No. 4 Tower and Vacuum Receiver.

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2

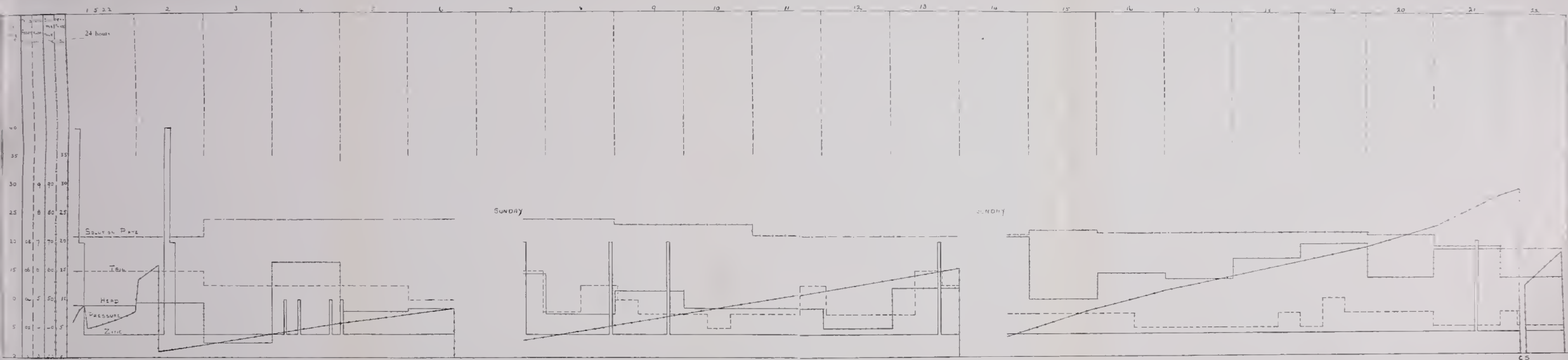
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1



PERIOD CHART OF GOLD PRECIPITATION BY ZINC DUST AT MODDERFONTEIN "B"

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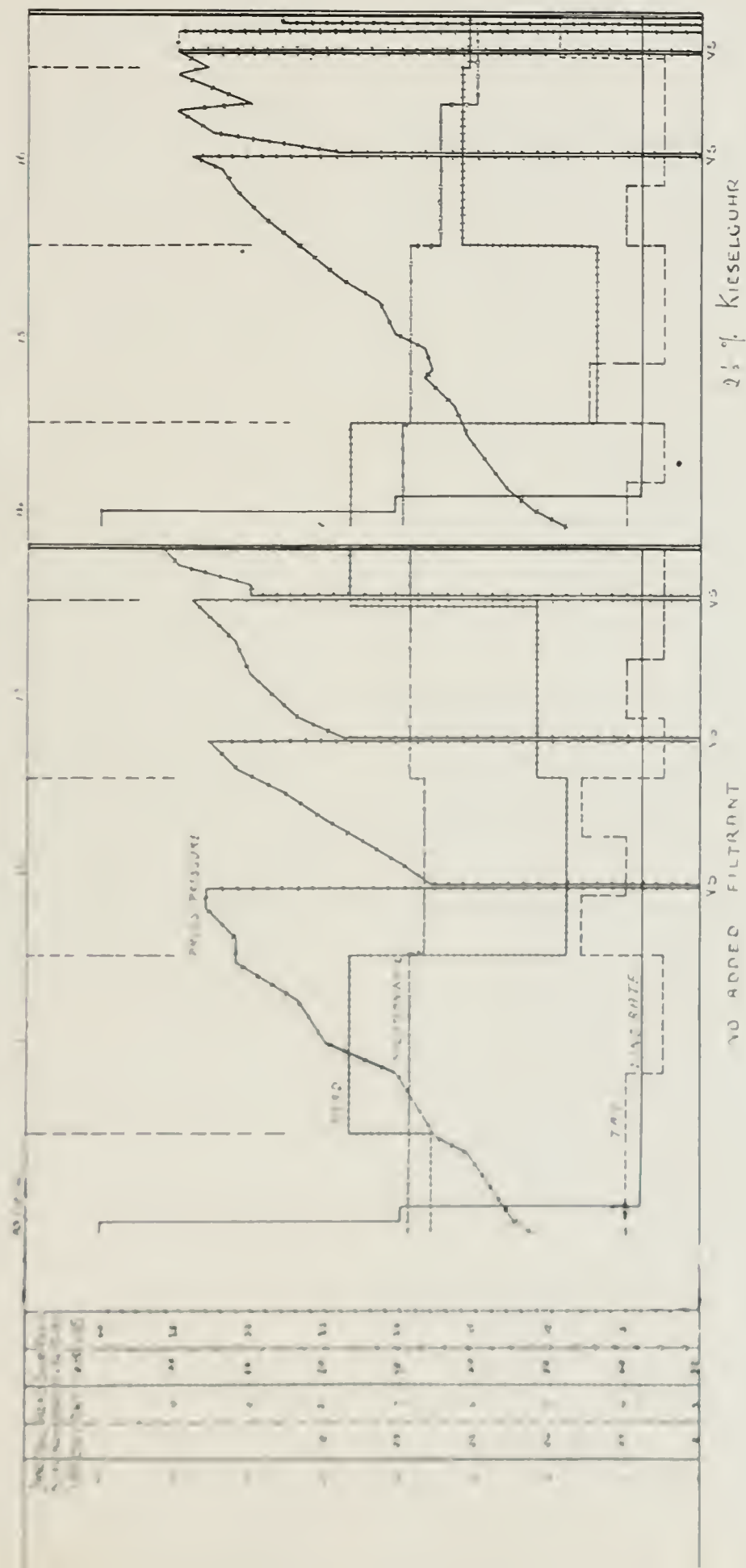
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PERIOD CHART OF GOLD PRECIPITATION BY ZINC DUST AT MODDERFONTEIN "B."

Run No. 3—73 hours.

Run No. 2—107 hours.



The President, in thanking the authors for the paper, remarked that they had undoubtedly put in a tremendous amount of work into it, and its practical value had to be conceded. He thought they had explained the process now in use at Modder B. clearly. Having been connected with zinc dust precipitation for many years, his first recollections of the practical process went back 26 years, when the principal idea was to throw in pounds, even hundredweights, of zinc dust into a tank and pump it into a filter press. The photograph the authors had shown that night, illustrating the small amount of zinc gold slime in the frame at the clean-up, was interesting; it certainly illustrated the evolution. Naturally they did expect improvement in 26 years. He well remembered in the early days of the process when they dealt with those large quantities, the dread of the clean-up, when often the zinc gold precipitate was hard and sometimes of the nature of a brick. On one occasion they had so much, and it was so hard that it had to be crushed in a gyratory crusher.

He thought the history of precipitation at Modder B., as outlined by the authors, was a record of perseverance and endeavour for improvement and efficiency. He hoped that they would have considerable discussion on the paper.

Mr. C. J. Gray seconded the vote of thanks to the authors for their very interesting paper. He could not, however, claim to know much about the subject as he was not a metallurgist, but he thought the paper illustrated the point which Mr. Wartenweiler, their President, had drawn attention to earlier, that in a Society in which different sciences in connection with mining were drawn together they did get a benefit. It was a great advantage to all of them to see points of view in connection with other branches of the subjects. If they lived alone, as it were, and confined their thoughts to their own specific subject, they must unavoidably become exceedingly narrow. They could never see how those different papers might give them ideas. He did not know exactly how the paper would benefit mining, but it had struck him that there might be something in the process which was not generally known, which might make it specially suitable in certain circumstances, say, at small mines or mines working on particular conditions. It might be of advan-

tage to mining men to know that such processes were in existence, and to know something at least of the principles which were concerned.

A point which he did not think had been perfectly clearly explained in the paper, was the amount of labour, skilled and unskilled, involved; it seemed there might be considerable saving in labour in comparison with other processes.

THE CORRELATION OF METALLURGICAL STATISTICS.

By H. A. WHITE.

(Printed in *Journal*, December, 1921.)

REPLY TO DISCUSSION.

Mr. H. A. White in reply to the discussion on his paper, said, as the amount of discussion was very small, perhaps that was only to be expected, as it was a new subject, and one that evidently had not succeeded in arousing any very great interest. He had to thank Dr. Caldecott for the kind remarks he had made, and he could only add, with regret, that the masses of valuable information which lay buried in their mine head offices should not have the advantage of the latest methods of statistical analysis applied to them, because he felt sure that, if that were done, a great deal of really valuable information might be extracted from what was at present chiefly waste paper.

THE COMBUSTION OF SOUTH AFRICAN COALS IN BOILER FURNACES.

By E. P. REIM, B.Sc.

(Printed in *Journal*, January, 1922.)

REPLY TO DISCUSSION.

I am grateful to Mr. Gray for his discussion on my paper, and for the additions and corrections which make the paper more complete.

I hope Mr. Gray will not think it a poor way of showing my gratitude, if I make one or two criticisms on his discussion. May I commence with his concluding paragraph: "His statement that one can estimate the

suitability of coals for different purposes by this means is absurd." Here Mr. Gray makes a dogmatic statement that my line of argument is absurd, without giving any reasons for this conclusion. Surely that attitude precludes all possibility of further discussion on that point, which I regret. I may mention that my views on this question in general are not isolated: A. L. Booth Esq., of Armstrong Whitworths, read a paper on this subject before the Iron and Steel Institute.* In the "Star" of the 3rd November, 1920, appeared the following extract, which I imagine referred to this same engineer:—"The selection of the particular coal to give the best results for certain purposes has always been an important matter for the engineer. To-day, with the enhanced cost of coal, it has become a vital problem. Hitherto it has been the custom to rely upon chemical compositions and tests of the heat value of coals, but the engineer of a leading firm which buys about $\frac{1}{4}$ million tons of coal every year for various uses, confirms the suspicion that something more is needed before the most economical coal in each case can be determined. He has worked out a series of microscopic tests by which various coals are classified, each class being most efficient for steam raising, or gas production or some other particular service. The method adopted is to grind the surface of a small sample of coal exceedingly smooth, fix it by the smooth surface to a piece of glass and grind away the remainder on the glass. When examined under the microscope this slice reveals the inner structure of the coal. The behaviour of the coal when fired corresponds to its structure, which thus provides an index to the use which ought to be made of the coal. The same investigation has found that very uniform results are given by samples from the one seam of coal, so that one or two tests are sufficient to determine the qualities of the seam. If this method is developed, it will become possible to order coals according to an exact specification, much as is now done with special steels and alloys."

Going in sequence through the points which Mr. Gray raised:—

I admit having introduced a certain amount of extraneous matter, but its entire irrelevancy is a matter of opinion. What appeals to me as having the least bearing

on the combustion of coal in boiler furnaces is spontaneous combustion, which subject Mr. Gray criticises me for dismissing in less than a column. Surely that is rather illogical.

I regret that some arithmetical mistakes have crept into my paper and some typographical errors, such as the omission of a decimal point in a position where its omission is obvious; also, naturally, the majority of my calculations are approximations by slide rule, but I do not see how the corrected figures make any difference to the validity of my argument.

I thank Mr. Gray for mentioning a point that I omitted, namely, that it is recognised that the temperatures to which coal has usually been subjected during formation has not exceeded 300° C. However, even at 300° C. gradual volatilisation must take place. Of course, higher temperatures must have been obtained in parts of the Natal Coalfields, where dyke has intruded immediately beneath the coal.

I am grateful to Mr. Gray for his discussion on the subject of impurities, as it contains some valuable information new to me.

Naturally the usual procedure is to design a steaming plant according to the coal available, but my idea in considering the combustion of coal for any particular purpose was, strictly speaking, a digression: I was thinking of the coal export trade, where we have to compete with other countries in supplying coal for various purposes in existing plants; for metallurgical and other work, as well as for steam raising.

On the combustion of coal; as it is very difficult to determine for any sample the exact form in which the oxygen is combined, the usual practice is to assume the oxygen to be combined with the hydrogen.*

Mr. Gray states: "It is generally admitted that calculations of the calorific values of coals from the figures obtained on ultimate analyses give fairly satisfactory results," but I think he should have added here, "if empirical formulae are used" he will no doubt agree that as I pointed out the calorific value obtained by multiplying the weights of the combustibles per pound of coal by their separate calorific values is inaccurate. The reason for including sulphur in the first calculation is that it is a combustible, although its effect is very small. In the second case I quoted an empirical

* Booth, on the Economic Selection of Coal, *Journal of the Iron and Steel Institute*, Vol. CXX, No. 2, 1920, p. 271.

* Fowler, on Steam Boilers, p. 112.

formula which includes the oxygen and nitrogen content, the term containing these being subtracted from the remainder, showing that as the oxygen and nitrogen content increases, more heat is required for the dissociation of the compounds in the coal.

I am sorry that Mr. Gray cannot follow my line of argument on the behaviour of coal on burning in a furnace, as I tried to make the description as plain as possible.

I am not complimented by Mr. Gray's suggestion that I am so lacking in an elementary knowledge of the subject as to consider the volatile matter and the fixed carbon in the coal as definite chemical entities. I might have been more correct in stating instead of fixed carbon "that portion of the coal which contains a higher percentage of fixed carbon than the surrounding portions." Portions are undoubtedly almost pure fixed carbon, such as the carbonised remains of conifer wood shown in Microphotographs 1 and 2; that portion of that particular sample being very little different from ordinary charcoal. Also Mr. Gray may not have noticed that I mentioned on p. 118: "It is probable also that the fixed carbon even is present in not altogether its free state." Naturally one gets gradations from the portions highest in fixed carbon to those lowest in fixed carbon, but the extremes may exist side by side in a specimen, e.g., Microphotograph 9, in which undoubted vegetable remains can be seen (unfortunately this is not as clear in the photograph as in the specimen itself), and it seems natural to suppose that the filling matter in between these and the particles of incombustible matter, is derived from the slimy ooze and so is high in volatile matter.

I fail to see any unreasonableness in my statement, "Regarding the ash, if this is fairly heat resisting, such as that containing chiefly silica and alumina, and is compactly distributed, it will retain its original shape." Taking a metallographical analogy of a bearing metal, if one knows the composition and properties of the softer and harder constituents and their mechanical distribution* one can form an idea as to what would be the most suitable use for the metal. Why should this not also apply to coal? Surely if we know the approximate composition and the properties of the constituents and their

mechanical distribution, we can form an idea as to what will take place during and after combustion. Regarding the microscopic examination of coal: knowing the properties of solvents such as pyridene, it seems too obvious to need comment that one can etch coal to show up local differences in carbon percentage.

I must thank Mr. Gray for the information he gives under the head of storage: his remarks confirm my ideas on the cumulative effect in spontaneous combustion. Naturally coals high in volatile matter are high in the more unstable compounds, and so they must oxidise more readily. Lomax showed that in spontaneous combustion other factors, which he investigated, *sometimes* took a more important part.

There is one misapprehension that I must correct, as a matter of courtesy, and that is that I was not responsible for the alterations to the boiler plant under consideration.

I much appreciate Mr. Gray's discussion, especially so as I am continuing my work on coal, and find constructive criticism a boon.

The meeting then terminated.

OBITUARY.

LT.-COL. C. B. SANER.

It is with deep regret that we have to record the death of Charles Benjamin Saner, one of the Past Presidents of the Society. He was the eldest son of the late Capt. Charles Taylor Saner, of Hull, an old pioneer of the Rand, and at one time manager of the Rietfontein Mine and the Van Ryn Gold Mine Estate. He was born on the 5th May, 1873, and obtained his mining education at the Royal School of Mines, London, where he took his Associateship in Mining in the year 1895. He became a member of this Society in 1902, and was a member of the Council during the years 1904, 1905, and 1908, Vice-President in 1909 and 1910, and elected President in June, 1911. He was also a member of the Institution of Mining and Metallurgy, of the Mine Managers' Association, and one of the founders and also a President of the now defunct Institute of Mine Surveyors.

In 1903, in association with Mr. Geo. Carter, he read a paper before this Society entitled "Underground Handling and

* V. Microphotographs by Johnston & Irwin in the *Journal of the S.A. Institution of Engineers*. May, 1922.

Transport of Ore." which is quite a classic on the subject, and in 1908 he contributed "Note on a Problem during Shaft Sinking." His Presidential Address delivered in February, 1912, was a very interesting review of the mining problems of the day.

When manager of the Turf Mines he sank the shaft there prior to the amalgamation of that property with the Village Deep. Later he managed the Transvaal Gold Mining Estates at Pilgrims Rest and the Luipaards Vlei Estate and Gold Mining Company.

He relinquished mining some seven years ago, and took up farming pursuits on the South Coast of Natal, and later at the Sunday's River settlement.

He was a keen volunteer and first saw military service in the South African War with the Railway Pioneer Regiment. Later he commanded the Witwatersrand Rifles, and was bitterly disappointed that reasons of health prevented him from leading his regiment in the South-West African Campaign and from serving overseas in the late War.

At college he was always a great favourite with his contemporaries, and his disposition was such that his popularity was maintained in after life.

The deepest sympathy is extended to his bereaved widow and three children and the other members of the family.

G. A. W.

BOOK REVIEWS

CONCENTRATION BY FLOTATION, by T. A. Rickard. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd. 1921.

Mr. Rickard, who is the editor of the *Mining and Scientific Press* of San Francisco, has compiled a third volume on flotation from articles which have appeared in that journal between 1915 and 1920. In addition to the twenty-two articles reprinted in two books published in 1916 and 1917, eighteen more recent papers are included in the present volume, and even those who have access to the journal will find this the latest compilation, convenient and valuable.

The articles have been selected to include all phases of the subject. A considerable number deal with theory and three sections concerned with the historical development of the process and the extraordinary patent litigation involved are of great interest,

particularly to those who are hoping for some improvement in patent laws and procedure.

The more practical aspects of flotation are discussed in papers describing large established plants in America, Canada, and Australia, while special articles are devoted to the difficult questions involved in the handling and smelting of flotation concentrate.

There are interesting articles on differential flotation, including descriptions of processes used or tried at Broken Hill (Australia) for the separation of zinc and lead sulphides; in these the present tendency towards methods involving only comparatively small changes in physical and chemical conditions during flotation is fully considered.

Of special interest in South Africa are the papers on the application of flotation to gold and silver ores by T. A. Rickard, and on the cyaniding of flotation concentrate by Charles Butters and J. E. Clenell. Papers on laboratory methods used in testing ores by flotation are also included.

The "glossary" at the beginning of the book contains several incorrect and misleading "definitions." Otherwise the book is an attractive publication.

H. R. A.

MANUAL OF FLOTATION PROCESSES, by Arthur F. Taggart. New York: John Wiley & Sons, Inc. London: Chapman & Hall, Ltd. 1921.

The value of Professor Taggart's book lies more in the practical information contained in it than in the explanations of fundamental principles given in the introductory chapter. The latter contains some quite extraordinary statements without any experimental evidence; thus we are told that there is a fundamental difference between flotation by mixing air, ore and impure water depending on whether the mixing is done by an agitator or by blowing the air into the already mixed ore and water through a porous diaphragm. Further, it is stated that in the agitation type of machine the air is continually going into solution only to be conveniently "precipitated" again on the sulphide particles. These ideas are somewhat novel to be presented in a "laboratory manual" without supporting evidence. There is a tendency in recent literature on flotation to differentiate the different methods of flotation as if considerable difference in principle were involved, and Professor Taggart carries this to an extreme.

Apart from the controversial matter in the introductory section the book is full of useful information, both for the student and practical man. The drawings of machines are detailed and the instructions on testing very elaborate. The flow-sheets given in the chapter on "Mill Data" are unfortunately confined to American mills; similar information on procedure at Broken Hill, where so much development in flotation has taken place, would have been a valuable addition. Some useful tables and metallurgical formulae are included in the book.

H.R.A.

A TEXTBOOK OF MINERALOGY, by Prof. E. S. Dana, third edition, revised and enlarged, by Prof. W. E. Ford; pp. 720. (London: Chapman & Hall, Ltd., 1922.) 25/- nett.

Dana's Textbook of Mineralogy is an old and familiar friend. In our student days we have sat up with him many a late night, and ever since he has been by our side. We have in our time introduced him to many a young aspirant after mineralogical knowledge, but we must confess that of late years, with so many other more attractive and up-to-date guides available, we have been rather hesitant to do so. It is now more than forty years since the first edition of the work appeared. Our own copy, now with battered covers and faded print, is the second edition, which first saw the light in 1898. No wonder that it has fallen somewhat behind the times, and that the student not infrequently consults it in vain. But textbooks, happily, unlike our other friends, can renew their youth and attractiveness, and in looking through the copy of the third edition, now before us, we are pleased to discover that such a transformation has occurred. We find that throughout it has been carefully and judiciously revised, and that too by one who has had in view not only the modernising of the work but also its presentation in such a form as to lessen as far as possible the peculiar difficulties that beset the student.

Descending to details, we observe that in the section on crystallography several minor faults, both of omission and commission, in the former editions have been rectified, while the treatment of the various projections of crystals has been not only amplified but considerably simplified. The rewriting of the appendix on the drawing of crystal

figures has resulted in a distinct improvement. In the section on physical mineralogy the most noteworthy improvement is in the treatment of the optical characters of minerals, which are dealt with at considerable length and in a very lucid manner. The descriptive portion of the work has been thoroughly revised and brought up to date, brief accounts of a large number of mineral species that have come to light since the issue of the second edition having been added.

The new edition is clearly printed and well provided with illustrations, many of them entirely new. From what has already been said it will be evident that the work is a distinct improvement on former editions and is well worthy of recommendation.

R.B.Y.

MINERAL LAND SURVEYING, by James Underhill, Ph.D., Mining Engineer, U.S., Mineral Surveyor for Colorado, third edition revised. Pp. 237. Plates 3. (London: Chapman & Hall, Ltd., 1922.) 17/6 nett.

This work describes the methods used at the present time in the survey of mineral lands in the western portion of the United States. The author does not claim for it the role of a textbook of general surveying which it certainly does not fill. Its value lies in the special subjects treated, viz., the methods of determining latitude and azimuth, use of solar attachments to the transit theodolite, conduct of location and patent surveys, and details of field notes and records. A chapter is devoted to the examination for commission as a United States Mineral Surveyor, and the appendix gives the instructions to the U.S. Mineral Surveyor.

As a professional vade mecum it must serve a very useful purpose to those practising in the Western States, but naturally would not contain much of general interest to the surveyor practising outside of these States.

Looking through the specimen notes one is struck by use of the antiquated method of recording courses by compass directions. Why not assume the direction of the meridian as zero and state all other directions as the angle made with the meridian? This is the method used in geodetic work, and is of equal utility in traversing. The conflict surveys are very mystifying.

G.A.W.

Notices and Abstracts of Articles and Papers.

CHEMISTRY

BIO-CHEMICAL METHOD.—Prof. Arthur Harden, D.Sc., Ph.H., F.R.S., of the Lister Institute of Preventive Medicine, read a paper before a joint meeting of societies on Bio-Chemical Method, dealing mainly with vitamins or accessory food factors.

Rats fed on purified foodstuffs lost weight and died, whereas on adding a small quantity of milk to the diet those rats which were not too far emaciated recovered.

The existence of three vitamins is now recognised, the fat soluble A vitamin, the water soluble B vitamin, and the anti-scorbutic C vitamin.

Fat soluble A vitamin.—The chief sources of this vitamin are animal fats, fish liver oils, green vegetables, and egg yolk. It has been found that weight for weight cod liver oil contains about 200 times as much A vitamin as butter. A very frequent symptom following upon the withdrawal of the fat soluble A vitamin from the diet is xerophthalmia, a disease of the eye characterised by opacity of the cornea.

This eye disease was also prevalent amongst young children in Denmark during the early years of the war, and was due to the children being fed on skimmed milk from which the A vitamin was removed with the butter.

Water soluble B vitamin is chiefly present in the germ of seeds, yeast, and egg yolk. Experiments on rats proved that the absence of this vitamin from the diet causes ultimate death, with symptoms very similar to death from beri-beri in man. This disease follows the consumption of a diet composed of polished rice from which all the vitamin has been removed with the cuticle.

Anti-scorbutic C vitamin occurs in green vegetables, especially cabbages, fruit juices (particularly orange, lemon, tomato, and to a less extent true line-jointed roots, tubers, turnips, and germinated seeds).

Guinea pigs and monkeys proved the most suitable subjects for study, the latter giving scurvy symptoms almost identical with those of man.

Effect of heat on vitamins.—This is important as bearing on the cooked food question. The A vitamin is not very susceptible to heat in the absence of air or ozone. When a fat containing A vitamin is saponified with the exclusion of air, the active vitamin is found unchanged in the unsaponifiable matter. The process of hardening of fats by hydrogenation invariably destroys the fat soluble accessory factor.

B vitamin is more stable than the A, being but slightly affected by either air or by moderate heating to boiling.

With C vitamin the aeration factor is very important. When cabbage is boiled its efficiency falls from 100 to 20. When orange juice is boiled in an airtube no diminution in activity occurs, but if boiled in air its efficiency gradually falls.

There is no doubt that the vegetable kingdom is the prime source of vitamins and that animals are incapable of synthesising them to any apparent extent.

The cod fish probably gets its large amount of fat soluble vitamin from the marine algae.—PROFESSOR ARTHUR HARDEN, D.Sc., Ph.D., F.R.S., *The Chemical Trade Journal and Chemical Engineer* (Society of Chemical Industry and Institute of Chemistry), January 13, 1922, p. 45. (H.D.B.)

PRACTICAL APPLICATIONS OF ELECTRO-ENDOMOSIS AND CATAPHORESIS.—The work which was issued from the laboratory of the Elektro Osmose Aktiengesellschaft remains the largest contribution to industrial application of the theoretical laws relating to electro-endomose and cataphoresis.

The Scherer patents applied to the purification of clay form the most interesting practical applications of the complicated physical laws dealing with colloids.

It has been discovered that suspensions of many varieties of clay could be so treated by a direct current of electricity as to bring about the deposition of the clay in a more or less dry state, on a negative pole.

It was found that all clays did not react, and some improvement was obtained by the use of suitable electrolytes.

The addition of colloid substances often proved advantageous.

The osmose machine applied to the separation of the suspended particles of clay is an interesting example of the application of comparatively recent physical chemical laws. On the anode of the osmose machine the negatively charged particles are deposited, and the moment a film of these exists over the anode, brought about by cataphoresis, electro-endomose comes into action, and the water in and around the clay is electrically driven through the capillary spaces resulting from the close contact of the clay particles deposited on the anode.

The process has been used for the recovery of peat from colloidal peat suspensions, splitting up of silicate of soda, and, by the use of suitable diaphragms, a very pure gelatine has been separated from a very low grade gelatine, and even from glue.

A 5 per cent. solution of this pure gelatine has successfully resisted bacterial growths for months.

The process has also been used in the tannin trade, and for ore separation. It has been found that if a finely ground ore be suspended in water in many cases it is possible to add traces of electrolyte which are selectively absorbed. On allowing such finely ground ore to fall through a column of water to which has been added the necessary quantity of suitable electrolyte and on passing a current through the water at right angles to the path of the falling particles, the charged particles are drawn on one side and fall into separate receptacles, bringing about concentration of the ore. Iron ores occurring in clay deposits have been concentrated by the removal of the clay substance on the lines above described.—DR. W. R. ORMSBY, *The Chemical Trade Journal and Chemical Engineer*, December 17, 1921, p. 770. (H.D.B.)

ZINC PURPURATE AS A REAGENT FOR MERCURY SALTS.—The reagent is prepared by heating 2 g. of uric acid with 2 c.c. of nitric acid (40° B., sp. gr. 1.38), diluting the solution with 2 c.c. of water, continuing the heating until a clear liquid is obtained and diluting this to 100 c.c.; if 10 c.c. of this liquid is boiled for five minutes with the addition of 2 g. of granulated zinc, a yellow-orange coloration develops due to the formation of zinc purpurate. When a mercuric salt solution is treated with a small quantity of the zinc purpurate solution and a few drops of sodium acetate solution, a peach-blossom-coloured precipitate of mercury purpurate is produced. The reaction may be obtained with as little as 0.4 mg. of mercury per c.c. of solution. Silver salts yield a violet-coloured precipitate with the reagent.—G. DENIGES, Bull. Soc. Pharm. Bordeaux, *Journal of Society of Chemical Industry*, October 15, 1921 p. 693A. (A.W.)

MINING

MINERS' NYSTAGMUS.—The first report of the Miners' Nystagmus Committee, which consists of Dr. J. S. Haldane, F.R.S. (Chairman), Professor E. L. Collis, M.D., M.R.C.P., Dr. T. L. Llewellyn (Secretary), Mr. G. H. Pooley, F.R.C.S., and Dr. W. H. Rivers, F.R.S., has been issued by the Medical Research Council of the Privy Council. The Committee have unanimously arrived at the following conclusions:—

(1) The essential factor in the production of miners' nystagmus is deficient illumination. Other factors, such as position during work, accidents, alcoholism, infections, malnutrition, hereditary predisposition, and errors of refraction, are of secondary importance only, while depth of workings, thickness of seams, and the ordinary gaseous impurities in mine air have no direct influence on the disease.

(2) The deficient illumination is due to the low illuminating power of the safety lamps generally used by coal miners, to the distance to which these lamps have to be placed from the objects which the miner has to look at, and to the great absorption of light by the coal and the coal-dust covered surfaces. In addition the effect of coal-dust or dirt in obscuring the lamp glasses, the choking of the wire gauze chimneys, and the presence of moisture or low oxygen percentage in mine air, all reduce the light given by oil lamps, while failing voltage, poor bulbs, or lack of proper attention, have similar effects on the illumination given by electric lamps.

(3) Workers at the coal face are more affected than other underground workers, and this appears to be due to the unrelieved blackness of the coal and the greater need for accurate vision.

(4) Distinct signs of nystagmus are present in a large proportion of coal miners, though only in a small proportion do the symptoms ever become so severe as to cause even temporary incapacity for work underground.

RECOMMENDATIONS BY THE COMMITTEE.

The Committee recommend that since incapacity due to nystagmus is rare among coal miners working with open lights, everything possible should be done to make the standard of illumination of the objects looked at by the

miner equal to that of an open-light pit. This can be effected at the coal face and elsewhere either by greatly increasing (to about two or three candles) the illuminating power of safety lamps, as ordinarily used, or by the use of an electric light capable of being fixed on a miner's head, belt, or other convenient position, so that the light is automatically brought nearer the working area, and does not impair clear vision by shining directly into the eyes. At parts of the pit other than the coal face the visibility of objects can be greatly increased by whitewashing, as well as by the stone dusting now obligatory for the prevention of explosions. The Committee believe that by the application of these remedies miners' nystagmus of sufficient severity to cause disablement can, by degrees, be entirely prevented.

During their investigations the Committee have noticed the prevailing belief among coal miners that miners' nystagmus causes permanent damage to, or even total loss of, sight if underground work is continued after the onset of symptoms. This belief, which is entirely erroneous, has led to much unnecessary suffering, and to the development of psychoneurotic symptoms in many cases. The disablement resulting leads to great loss to the miners, and increases the charges on the industry and general public.

AN INCAPACITY APPEAL.

The Committee recommend that both workman and employer be granted power to appeal to the medical referee, at intervals of not less than six months from the original certificate of disablement or date of last appeal, to assess the incapacity present. In this appeal the medical referee should certify that the man is either: (1) Totally incapacitated; (2) partially incapacitated (a) fit for surface work, (b) fit for suitable work below ground; (3) not incapacitated.—COMMITTEE, *Coal and Iron and By-Products Journal*, April 22, 1922. (J.A.W.)

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INDEX

TO

VOL. XXII.

INDEX TO VOL. XXII., 1921-1922.

(COMPILED BY THE SECRETARY, H. A. G. JEFFREYS, O.B.E.)

The portions in Italics refer to Original Notes and Papers read before the Society.

A		PAGE.		PAGE.
Abstracts, Chemical, 19, 26, 40, 65, 89, 107, 136, 162, 166, 194, 263			Analysis of Babbit Metal, H. C. Boehmer, J. R. Gordon and C. W. Simmons	65
—, Metallurgical, 20, 43, 69, 92, 110, 141, 162, 171, 198, 233			— of <i>Far East Rand Ore</i> , F. W. Watson, <i>Corrigendum</i>	19
—, Mining, 43, 92, 111, 142, 163, 173, 199, 236			— of Graphite, Method for Rapid, G. B. Taylor and W. A. Selvig ...	66
—, Miscellaneous, 27, 44, 96, 113, 175, 203			— of Monel Metal, Rapid Method for the, P. Covitz	20
Accounts		239	Anderson, W.—On A Resumé of Standard Methods of Sampling, Analysis and Classification of Coal	155
Acid and Alkaline Decomposition of Potassium Cyanide, The—G. Harker		166	Anemometer	92
<i>Acidity of Mine Waters, The</i> , F. W. Watson and R. A. Cooper, 30; Discussion, 32, 159; <i>Reply to</i> ...		230	Anjon, G.—Volumetric Estimation of Potassium and its Application to the Analysis of Fertilisers ...	65
Adam, H. R.—On Miners' Phthisis ...		225	Annual Ballot Scrutineers	205
—, on Notes on the Manipulation of Osmiridium Concentrate		154	— Dinner	241
—, on Technical Examination of Lubricating Oil and Grease		219	— Report of Council	239
—, on Vote of Thanks to Retiring President		247	Anthracoal, D. Markle	175
Address, Changes of, 20, 28, 44, 72, 96, 116, 144, 164, 176, 236, 264			Anthrax Spores, Resistance of, to Various Treatments, A. Muller ...	44
Air, Estimation of, Nitrous Fumes in, J. Moir		166	<i>Antimonial Gold Ore at the Globe and Phoenix Mine, Southern Rhodesia, Treatment of</i> , F. E. Robinson, <i>Reply to Discussion</i> ...	62
—, Liquid, Explosives L. W. Winkler ...		26	Arsenic, New Procedure for the Estimation of, J. Cribier	168
— Pressures and Drilling Speeds of Hammer Drills, H. W. Seamon ...		95	Art of Lime Burning, The, G. B. Wood ...	140
—, Purifying, by Electricity		116	Assay Balance, Rider Stand for, John Watson	248
— Velocities, Measurement of, Jas. Cooper		92	Assay Muffles, Firing, with Pulverised Coal, E. N. Hamilton	166
Alcohol, Power		170	— of Gold Bullion, The, A. Westwood	233
Alcoholic Fermentation as a Source of Glycerine, K. Schweizer ...		167	Assayers and Miners' Phthisis	225, 228
Alkali Cyanides, The, J. Meyer		91	Assaying Oil Shales for Oil Yield, Retort for, L. C. Karrick	115
—, Standard, Guanadine Carbonate as a, A. H. Dodd		42	Assessment on Constituent Societies by Associated Scientific and Technical Societies of South Africa ...	145
Alkaline Decomposition, The Acid and of Potassium Cyanide, G. Harker		166	Associated Scientific and Technical Societies of South Africa, 47, 73, 74, 145, 147, 177, ...	241
Allen, William—On Miners' Phthisis ...		25	Associates, New, 24, 45, 73, 145, 178, ...	205
Alloys		142	Atoms, The Stability of—E. Rutherford ...	195
Alternate Current, Mineral Concentration by, W. M. Merdy		159	Auditors, Honorary	242, 247
Aluminium, The Volumetric Estimation of, E. J. Kraus		167	Austin, L. S.—The Metallurgy of the Common Metals (Book Review) ...	165
Ambulance, Competitions, Mine		135	Automatic Cone Classifier Underflow Regulator, H. Bruzier	74
Anomalous Process, The Claude, J. H. West		167	Auxiliary Ventilation, Methods of, D. Harrington and B. W. Dyer ...	43
— Sulphate of, The Production of, from Coal, O. Lazar		91		
Anaconda Copper Mining Company, Stope Cost Records and Mine Contracts of the, C. J. Bertram ...		202	B	
—, Underground Fire Prevention by the, E. M. Norris		201	Babbit Metal, Analysis of, H. C. Boehmer, J. R. Gordon and C. W. Simmons	65
Analysis, Fuel		108		
—, <i>Notes on Technical Methods of</i> , A. Whitby & J. P. Beardwood <i>Reply to Discussion</i>		156		

	PAGE.		PAGE.
Cataphoresis. Electro-Endomosis and, Practical Applications of. W. R. Ormandy	263	Coal, The Production of Sulphate of Ammonia from. O. Lazar	91
Cement, Portland. Plant at Lourenço Marques	203	Coals, The Combustion of South African, in Boiler Furnaces. E. P. Reim, 117; Discussion, 192; Reply to	258
Cementation for Combating Fires in Coal Mines	144	Cocking, T. T.—Indicators and Hydrogen Ion Concentrations	197
— Process. Application of the, to a Battery Foundation. B. Schlesinger	76	Coke, Metallurgical, The Froth Flotation Process and. E. Bury	173
Cements, Action of Lime in Magnesium Oxychloride. M. Y. Seaton, C. R. Hill and L. C. Stewart	90	—, The Desulphurising Action of Hydrogen on. A. R. Powell	43
Centrifugally Cast Pipe. A. F. Macal-lum	28	Coker, E. G.—The Effects of Scratches in Material	113
Chain Grip Attachment on Wire Ropes	155	Coking Process, A Study of the Reactions of Coal Sulphur in the. A. R. Powell	40
Changes of Address. 20, 28, 44, 72, 96, 116, 144, 164, 176, 236, 264	264	Colorimetric Method of Determining Hydrogen Ion Concentration, The. N. Evers	136
Chapman, L. W.—Salts Refining Plants at Owen's and Searle's Lakes	89	Combustion of South African Coals in Boiler Furnaces, The. E. P. Reim, 117; Discussion, 192; Reply to	258
Chemistry, Abstracts, 19, 26, 40, 65, 89, 107, 136, 162, 166, 194, 267	263	—, Spontaneous, of Coal in Mines	142
— in Relation to the Future Supply of Liquid Fuel. H. Hibbert	67	Commercial Electrolytic Iron. F. A. Eustis	171
Chilton, J.—The Endless Rope Haulage at Modder East, 184; Discussion	187	Compressed Air, Ventilation Doors in Arizona Copper Mines Operated by. E. D. Gardner	164
Chloride Volatilisation	43	Concentrate, Osmiridium, Notes on the Manipulation of. R. A. Cooper, 152; Discussion	154
— Process. T. Varley and C. Stevenson	71	Concentration by Flotation. T. A. Rickard (Book Review)	261
Christy, S. B.—Electro-Deposition of Gold and Silver from Cyanide Solutions	20	—, Mineral, by Alternate Currents. W. M. Mordy	199
Chromium (in Stainless Steel)	138	Cone Classifier, Automatic. E. M. Weston	232
Clarifying Agent, Magnesium Carbonate as a	198	— —, Underflow Regulator, Automatic. H. Brazier	74
Classifier, Automatic Cone, Underflow Regulator. H. Brazier	74	Consumption, Miners'. A. J. Lauza and D. Harrington	112
Classifiers, Automatic. E. M. Weston	232	Contributions and Correspondence, 61	232
Claude Ammonia Process, The. J. H. West	167	— Towards Maintenance of the Associated Scientific and Technical Societies of South Africa, 145	241
Cleaning Metallurgical Smoke, The Feld Scrubber for. W. F. Lamoreaux	234	Converters, Vacuum	92
Clevenger, G. H., Mulock, F. and Harris, W.—Dusting and Volatilisation Losses during Melting Cyanide Precipitate and Air Refining of Bullion	198	Cooper, Jas. Measurement of Air Velocities	92
Coal, A Review of Standard Methods in Sampling, Analysis and Classification of. A. Trevor Williams, 1. Discussion, 36, 155, 189; Reply to	157	Cooper, R. A.—Notes on the Manipulation of Osmiridium Concentrate, 152; Discussion	154
— Determination of Calorific Value of	4	—, Osmiridium in the Banket Reef	78
— Determination of Nitrogen in	10	Cooper, R. A. and Watson, F. W.—The Acidity of Mine Waters, 30; Discussion, 32, 159; Reply to	230
— Dry Cleaned	96	Copper, a very Sensitive Reagent for; The Kastle-Meyer Reagent. P. Thomas	197
— Moisture in	5	—, New Method for the Volumetric Estimation of. S. Minovici and A. Jonsson	197
— Pillar Extraction from Two Seams and Surface Effects. W. T. Heslop, 54; Discussion, 61, 84, 190; Reply to	241	— Precipitating Apparatus, Development of. J. Irvine, Jun.	110
— Pulverised, Firing Assay Muffles with. E. N. Hamilton	106	Cornog, J. Preparations of Carbonate Free Sodium Hydroxide	195
— Quick Estimation of Sulphur in	139	Correlation of Metallurgical Statistics, The. H. A. White, 97; Discussion, 192; Reply to	258
— Spontaneous Combustion of, in Mines	142		
— Sulphur in the Coking Process, A Study of the Reactions of. A. R. Powell	40		
— Tars for Road Binding. Latex	162		

	PAGE.
Correspondence, Contributions and	64, 232
Corrigenda	19, 203
Corrosion in Centrifugally Cast Pipes	28
Corrosion of Iron and Steel, The. J. N. Friend	139
— of Metal Work in Mines	30
Council, Annual Report of	239
—, Attendances	242
Covitz, P.—Rapid Method for the Analysis of Monel Metal	20
Cribier, J.—New Procedure for the Estimation of Arsenic	168
Crowe Method of Vacuum De-aeration	253
Crucibles, Platinum, The Handling of Fusion in. L. L. de Koninck	140
Cupel, Absorption of Gold in the	233
Cyanidation, Lime Consumption in. R. W. Perry	162
Cyanide, Low-grade	90
—, —, N. W. Buch	206
—, Plants, Recovery of Zinc from	196
—, Potassium, The Acid and Alkaline Decomposition of. G. Harker	166
— Sodium	167
— Solution, Works, Apparatus and Method for Standardising. W. D. Dodds	205
— Solutions, Electro-Deposition of Gold and Silver from. S. B. Christy	20
Cyanides, The Alkali. J. Meyer	91

D

Dana, E. S.—A Textbook of Mineralogy (Book Review)	262
De-aeration of Solution, Gold Precipitation by Zinc Dust and in Conjunction with, at Modderfontein "B". S. Newton and L. L. Fewster, 249; Discussion	258
De-aeration, Vacuum, Crowe Method of	253
Decimalising Standard Measures. H. Williamson	204
De-gassing and Purification of Boiler Feed Water. Paul Kestner	19
Delf, E. Marion.—Methods used in the Detection and Investigation of Vitamines. Discussion	63
Deniges, G.—Zinc Purpurate as a Reagent for Mercury Salts	264
Desulphurising Action of Hydrogen on Coke, The. A. R. Powell	43
Detection of Carbon Monoxide	108
Determination of Molybdenum. J. P. Bonardi and E. P. Barrett	41
Determination of Nitrous Fumes in Air. J. Moir	42
Development of the Blast Furnace, The J. Henderson, 178; Discussion	183
— of the Rod Mill, The. E. H. Robie	69
Device for Testing the Permeability of Slime, A. B. L. Gardiner	207
— for Utilising Worn Tube Mill Bars. J. R. Thurlow	248
Devices of Practical Advantage, Exhibition and Demonstration of, 74, 146, 205, 207,	248

	PAGE.
Dewar, T. N.—Occurrences of Fire Damp in the Far East Rand; Discussion, 34; Reply to	62
Dewar, T. N.—On Coal Pillar Extraction from Two Seams and Surface Effects	61
Diering, J. H. A.—On Some Notes on the Pilgrim's Rest Goldfields	160
Differential Flotation of Lead-Zinc Ores	111
Dinner, Annual	241
Dipping Needle	94
Distribution of Gold in Banket Ore Classified Products, with Reference to Milling and Cyaniding Operations—F. Wartenweiler. Discussion, 24, 35, 106; Reply to	187
Dixon, J. M.—On Mill Finger Safety Device	47
Dodd, A. H.—Guanadine Carbonate as a Standard Alkali	42
Dodds, W. D.—Apparatus and Method for Standardising Works Cyanide Solution	205
Drills, Hammer, Air Pressures and Drilling Speeds of. H. W. Seamon	95
Dry Cleaned Coal	96
Drying, Vacuum, The Principles of. C. O. Lavett and D. J. van Marle	96
Duralumin	142
Dust Fuel Boilers	119
Dust Trap, A	25
Dusting and Volatilisation Losses during Melting Cyanide Precipitate and Air Refining of Bullion G. H. Clevenger, F. Mulock and W. Harris	198
Dyer, B. W., and Harrington, D.—Methods of Auxiliary Ventilation	43

E

Effects of Scratches in Material, The. E. G. Coker	113
Election of Officers, Associated, Scientific and Technical Societies of South Africa	74
Electric Furnaces for Silver, Gold and Metals of Low Melting Point. J. Herlenius	71
Electricity, Purifying Air by	116
Electro-Deposition of Gold and Silver from Cyanide Solutions. S. B. Christy	20
Electro-Endomosis and Cataphoresis, Practical Applications of. W. R. Ormandy	263
Electrolytic Estimation of Gold, Palladium and Platinum. W. H. Treadwell	162
— Iron, Commercial. F. A. Enstis	171
Elements of Engineering Geology. H. Ries and T. L. Watson (Book Review)	161
Ellis, D.—Iron Bacteria in Relation to the Incrustation of Pipes	175
Endless Rope Haulage at Modder East, The. J. Chilton, 184; Discussion	187

	PAGE.
Engine, Hoisting, The World's Largest	41
Erickson, E. T.—Detecting Small Quantities of Petroleum (Mineral Oil)	27
Erosion of Bronze Propellers, The. O. Silberrard	92
Essential Services, Maintenance of, During the Strike	177
Estimation of Small Amounts of Iron as Thiocyanate, R. Wilstatter	140
Etching Reagents	68
Ethylene Present in Coke-Oven Gas as Alcohol and its Derivatives, Fixation of, E. Bury	26
Eucalypts and their Essential Oils (Review), E. J. Parry	44
Eustis, F. A.—Commercial Electrolytic Iron	171
Evaluation of Zinc Dust, A New Method for the, Bullenheimer	166
Evers, N.—The Colorimetric Method of Determining Hydrogen Iron Concentration	136
Excursions	241
Exhibition and Demonstration of Devices of Practical Advantage, 74, 146, 205, 207	248
Exhibition, The	241
Explosives, Liquid Air, L. W. Winkler	26

F

<i>Far East Rand, Occurrences of Fire Damp on the, T. N. Dewar; Discussion, 34; Reply to</i>	62
<i>Features of Metallurgy of a Refractory Gold Ore, F. Wartenweiler, 147; Discussion</i>	152
Feld Scrubber for Cleaning Metallurgical Smoke, The, W. F. Lamoreaux	234
Fermentation, Alcoholic, as a Source of Glycerine, K. Schweizer	167
Ferreira Deep Disaster	147
Ferretting out Jobs in New York; How Engineers are	111
Fertilisers, Analysis of, Volumetric Estimation of Potassium and its Application to the, G. Anjon	65
Fertilisers, Phosphatic, Treatment of Phosphates by Calcination with a View to their Employment as	90
<i>Feuwerker, L. L. and Newton, S.—Gold Precipitation by Zinc Dust and in Conjunction with the Denaturation of Solution of Modderfontein "B" 249; Discussion</i>	258
Fibrosis	220
Filter Cloths, Industrial, A. Wright	176
Filter Press, An Improved Type of, C. D. Burchenal	110
Fire Fighting, Masks as a Protection in, H. F. Bain	174
— Prevention and Fighting in Metal Mines, H. M. Wollin	190
—, Underground, by the Anaconda Copper Mining Company, E. M. Norris	201
Fires, Mine, Extinguished by Sealing, D. Bunting	95

	PAGE.
Fixation of Ethylene Present in Coke-Oven Gas as Alcohol and its Derivatives, E. Bury	26
Flotation, Concentration by, T. A. Rickard, (Book Review)	261
—, Differential, of Lead-Zinc Ores...	111
—, Process, The Froth, and Metallurgical Coke, E. Bury	173
— Processes, Manual of, A. F. Taggart (Book Review)	261
—, The Function of Oil in, D. W. Leeke and R. H. Jarvis	235
Flourspar, The Separation of Sphalerite, Silica and Calcite from, J. Gross	141
Formic Acid, Determination of, in the Presence of Hydrocyanic Acid, G. Harker	166
Friend, J. N.—The Corrosion of Iron and Steel	139
Froth Flotation Process and Metallurgical Coke, The, E. Bury	173
Fuel Analysis	108
— Economy Recommendations in England	107
—, Liquid, Chemistry in Relation to the Future Supply of, H. Hibbert	67
Fuel Research Board	169, 170
— Board's Views of Low Temperature Carbonisation, G. Beilby	169
Fuller's Earth, Preparation of (For Treatment of Mineral Oils), W. C. Phalen	26
Function of Oil in Flotation, The, D. W. Leeke and R. H. Jarvis	235
Furnace, Blast, The Development of the, J. Henderson, 178; Discussion	183
Furnaces, Boiler, The Combustion of South African Coals in, E. P. Reim, 117; Discussion, 192; Reply to	258
Fusions in Platinum Crucibles, The Handling of, L. L. de Koninck	140

G

Gas, Power, from Sewage, J. D. Watson	175
Gasolin, Selenium and Tellurium Compounds as Intensifiers of	195
Gardiner, B. L.—A Device for Testing the Permeability of Slime	207
Gardner, E. D.—Ventilation Doors in Arizona Copper Mines Operated by Compressed Air	164
Geological Methods of the Homestake Gold Mining Co., L. H. Wright	174
Geologists' Field, Handbook for, C. W. Hayes (Book Review)	233
Geology, Engineering, Elements of, H. Ries and T. L. Watson (Book Review)	101
Gibson, A. The Magnetometer	94
<i>Globe and Phoenix Mine, Southern Rhodesia, Treatment of Antimonial Gold Ore at the, V. E. Robinson, Reply to Discussion</i>	62

	PAGE.		PAGE.
Glycerine, Aleoholic Fermentation as a Source of. K. Schweizer	167	Gray, Jas.—On Vote of Thanks to Retiring President	247
Glynn's Reef, The	83	<i>Grease, Lubricating Oil and Technical Examination of. F. W. Watson and H. D. Bell, 211; Discussion</i>	219
Goadby, K.—Lead Poisoning	170	Greensand, Action of Lime on. R. Norris Shereve	66
Gold and Silver from Cyanide Solutions, Electro-Deposition of. S. B. Christy	20	Gross, J.—The Separation of Sphalerite, Silica and Calcite from Fluorspar	141
— Bullion, The Assay of. A. Westwood	233	Guanadine Carbonate as a Standard Alkali. A. H. Dodd	42
<i>Gold in Banket Ore Classified Products with Reference to Milling and Cyaniding Operations, Distribution of. F. Wartenweiler; Discussion, 24, 35, 106; Reply to</i>	187	Gunitite in Inclined Shafts. J. Knox and O. Potter	94
— Ore, Baking a. P. T. Bruhl	43	Gye, W. G.—On Miners' Phthisis	222
— —, Refractory, Features of Metallurgy of a. F. Wartenweiler, 147; Discussion	152		
—, Palladium and Platinum, Electrolytic Estimation of. W. H. Treadwell	162	H	
— <i>Precipitation by Zinc Dust and in Conjunction with the De-aeration of Solution at Modderfontein "B." S. Newton and L. L. Fewster, 249; Discussion</i>	258	Hall, T. D.—The Lime Requirements of Some South African Soils	139
—, Quantitative Precipitation of, by Means of the Electric Current. W. D. Treadwell	107	Halogens, The Use of Mercuric Nitrate instead of Silver Nitrate in the Estimation of the. I. M. Kolt-hoff and A. Bak	197
—, Visible, in Banket Ore, Microphotographs of	184	Hamilton, E. N.—Firing Assay Muffles with Pulversised Coal	166
<i>Goldfields, Pilgrim's Rest, Some Notes on the. H. C. F. Bell, 79; Discussion, 85, 160; Reply to</i>	231	Hammer Drills, Air Pressures and Drilling Speeds of. H. W. Seamon	95
Gordon, J. R., Bochmer, H. C., and Simmons, C. W.—Analysis of Babbit Metal	65	Handbook for Field Geologists. C. W. Hayes (Book Review)	233
Graphite, Analysis of, Method for Rapid. G. B. Taylor and W. A. Selvig	66	Harden, A.—Bio-Chemical Method... ..	263
Gravimetric Determination of Bismuth as Phosphate. W. R. Schoeller and E. F. Waterhouse... ..	66	Harker, G.—The Acid and Alkaline Decomposition of Potassium Cyanide with a Note on the Determination of Formic Acid in the Presence of Hydrocyanic Acid	166
Gray, C. J.—Mineral Identification Sheets and Sieves	78	Harrington, D. and Dyer, B. W.—Methods of Auxiliary Ventilation	43
— —. On Coal Pillar Extraction from Two Seams and Surface Effects	160	Harrington, D. and Lanza, A. J.—Miners' Consumption	112
— —. On Fire Damp in the Far East Rand	34	Haris, W., Clevenger, G. H. and Mulock, F.—Dusting and Volatilisation Losses during Melting Cyanide Precipitate and Air Refining of Bullion	198
— —. On Gold Precipitation by Zinc Dust and in Conjunction with De-aeration of Solution at Modderfontein "B"	258	<i>Haulage, The Endless Rope, at Modder East, J. Chilton, 184; Discussion</i>	187
— —. On Miners' Phthisis	225	Hayes, C. W.—Handbook for Field Geologists (Book Review)... ..	233
— —. On Vote of Thanks	247	Henderson, J.—The Development of the Blast Furnace, 178; Discussion	183
Gray, Jas.—On Contributions Towards Maintenance of the Associated Scientific and Technical Societies of South Africa	146	Herlenius, J.—Electric Furnaces for Silver, Gold and Metals of Low Melting Point	71
— —. On List of Members	248	<i>Heslop, W. T.—Coal Pillar Extraction from Two Seams and Surface Effects, 54; Discussion, 61, 88, 160; Reply to</i>	231
— —. On Notes on the Manipulation of Osmiridium Concentrate	154	Hibbert, H.—Chemistry in Relation to the Future Supply of Liquid Fuel	67
— —. On Presidential Address	53	Hill, C. R., Seaton, M. Y. and Stewart, L. C.—Action of Lime in Magnesium Oxychloride Cements	90
— —. On Rider Stand for Assay Balance	249	Hill, J. M.—Platinum in 1921	172
— —. On the Action of the Associated Scientific and Technical Societies during the Strike	177	Hingle, L. D.—The Preservative Treatment of Mine Timber	175

	PAGE.
Hoisting Engine, The World's Largest	44
Homestake Gold Mining Co., Geological Methods of the. L. B. Wright	174
Honour, The Society's Roll of	65
Hoolamite	108
Hoover, C. R.—The Detection of Carbon Monoxide	169
Humidity Table for the Wet and Dry bulb Thermometer, A Convenient	171
Hydrocyanic Acid, Determination of Formic Acid in the Presence of. G. Harker	166
Hydrogen Ion Concentration, The Colorimetric Method of Determining. N. Evers	136
— Concentrations, Indicators and T. T. Cocking	197
— The De-sulphurising Action of, on Coke. A. R. Powell	43
Hydrogenation, New Method of	195

I

Identification Sheets and Sieves, Mineral. C. J. Gray	78
Imperial Mineral Resources Bureau, Fuel Analysis	108
Inclined Shafts, Gunite in. J. Knox and O. Potter	94
Incrustation of Pipes, Iron Bacteria in Relation to the. D. Ellis	175
Indicators and Hydrogen Ion Concentrations. T. T. Cocking	197
Industrial Disturbances.... 147, 165	177
— Filter Cloths. A. Wright	176
— Respirator	116
<i>Influence of Soluble Silica and Calcium Salts on Precipitation, Notes on the. J. Hayward Johnson; Reply to Discussion</i>	61
Ingall, D. H.—The Relation between Mechanical Properties and Microstructure in Pure Rolled Zinc	70
Innes, J., at Presentation of Medals	47
Investigating Strata by Percussion Waves	236
Ion, Hydrogen, Concentration, The Colorimetric Method of Determining. N. Evers	136
— Concentrations, Indicators and. T. T. Cocking	197
<i>Ireland, H. J.—The Kala-Thermometer and its Practical Uses in Mining, Addendum</i>	21
— On Methods used in the Detection and Investigation of Vitamines	63
Iridium 70, 78, 152, 173	209
Iron and Steel Industry in South Africa	183
— The Corrosion of. J. N. Friend	139
— Thiocyanate, Estimation of Small Amounts of. R. Wilstatter	140
— Bacteria in Relation to the Incrustation of Pipes. D. Ellis	175
— Blast Furnace Practice, Present Day. H. Sweter	198

	PAGE.
Iron, Commercial Electrolytic. F. A. Eustis	171
— Ores, Leaching, for Phosphorus. R. M. Winslow	141
—, Stainless	169
Irving, J. Jnr.—Development of a Copper Precipitating Apparatus	110

J

Jarvis, R. H. and Leeke, D. W.—The Function of Oil in Flotation	235
Jobs in New York, How Engineers are Ferreting out	114
<i>Johnson, J. Hayward.—Notes on the Influence of Soluble Silica and Calcium Salts on Precipitation; Reply to Discussion</i>	61
—, —. On Features of Metallurgy of a Refractory Gold Ore	152
Jonescu, A. and Minovici, S.—New Method for the Volumetric Estimation of Copper	197
Journal, Printing of	73
Journals and Papers	240

K

Karrick, L. C.—Retort for Assaying Oil Shales for Oil Yield	115
Kastle-Meyer Reagent: A Very Sensitive Reagent for Copper. P. Thomas	197
Kata-Thermometer	32
<i>Kata-Thermometer and its Practical Uses in Mining, The.—H. J. Ireland, Addendum</i>	21
Kestner, Paul.—De-gassing and Purification of Boiler Feed Water	19
King, A.—On Distribution of Gold in Banket Ore Classified Products with Reference to Milling and Cyaniding Operations	36
Knox, J. and Potter, O.—Gunite in Inclined Shafts	94
Kolthoff, I. M. and Bak, A.—The Use of Mercuric Nitrate instead of Silver Nitrate in the Estimation of the Halogens	197
Koninek, L. L. de.—The Handling of Fusions in Platinum Crucibles	140
Kraus, E. J.—The Volumetric Estimation of Aluminium	167

L

Lamoureux, W. F.—The Feld Scrubber for Cleaning Metallurgical Smoke	234
Language Reef, The	81
Lanza, A. J. and Harrington, D.—Miners' Consumption	112
Lavaud, de—Centrifugally Cast Pipe	28
Lavett, C. O. and Van Marle, D. J.—The Principles of Vacuum Drying	96
Lazar, O.—The Production of Sulphate of Ammonia from Coal with a Description of the Works of the Natal Ammonium, Ltd	91

	PAGE.
Leaching Iron Ores for Phosphorus. R. M. Winslow	141
Lead in Peaty Waters, Detection of. T. Tickle	194
— Poisoning. K. Goadby... ..	170
Lead-Zinc Ores, Differential Flotation of	111
Lectures Arranged by Associated Scientific and Technical Societies of South Africa	73
Leeke, D. W. and Jarvis, R. H.—The Function of Oil in Flotation ...	235
Legal Advisers, Honorary... ..	242, 247
Lime Burning, The Art of. G. B. Wood	140
— Consumption in Cyanidation. R. W. Perry	162
— in Magnesium Oxychloride Cements, Action of. M. Y. Seaton, C. R. Hill and L. C. Stewart...	90
— — Quicklime and Hydrated Lime, Determination of Available. A. I. Whitson	162, 168
— on Greensand, Action of. R. Norris Shereve	66
— Requirements of Some South African Soils, The. T. D. Hall ...	139
Liquid Air Explosives. L. W. Winkler	26
— — Mine Rescue Apparatus, New. H. Briggs	163
— Fuel, Chemistry in Relation to the Future Supply of. H. Hibbert	67
Loading in Mines, Scraping and. W. Royce	173
Lohman, W. and Von der Heide, C.—Detection of Saccharin in Wine	166
Longinescu, G. G. and Theodorescu, G. P.—Separation of Metals of the Second Group	66
Low-grade Cyanide	90, 206

M

Macallum, A. F.—Centrifugally Cast Pipe	28
Madden, J.—An Improved Mercury Bottle	146
Magnesium Carbonate as a Clarifying Agent	198
— Pyrophosphate, Determination of Phosphoric Acid as. D. Balareff	194
Magnetic Separation	199
Magnetometer, The. A. Gibson	94
Markle, D.—Anthracol	175
Masks as a Protection in Fire Fighting. H. F. Bain	174
Mavrogordato, A.—On Miners' Phthisis	226
Measurement of Air Velocities. Jas. Cooper	92
Medals, Presentation of, Research Endowment Fund	45
Medical Research, South African Institute for, Johannesburg, Visit to the	135
Members, New, 29, 45, 73, 145, 178, 205,	247
Memorial, War	242
Mercuric Nitrate, The Use of, instead of Silver Nitrate in the Estimation of the Halogens. I. M. Kolthoff and A. Bak	197
Mercury Bottle: An Improved. J. Madden	146

	PAGE.
Mercury-Salts, Zinc Purpurate as a Reagent for. G. Deniges	264
Merrill Precipitation Press	249
Metal Mines, Fire Prevention and Fighting in. H. M. Wolflin ...	199
Metallurgical Abstracts, 20, 43, 69, 92, 110, 141, 162, 171, 198,	233
— Smoke, The Feld Scrubber for Cleaning. W. F. Lamoreaux...	234
— Statistics, The Correlation of. H. A. White, 97; Discussion, 192; Reply to,	258
Metallurgy, Non-Ferrous, Modern Development in. W. R. Barclay	141
— of the Common Metals, The. L. S. Austin (Book Review)	165
Metals of Low Melting Point, Electric Furnaces for Silver, Gold and. J. Herlenius	71
— — the Second Group, Separation of. G. G. Longinescu and G. P. Theodorescu	66
Methods used in the Detection and Investigation of Vitamines. E. Marion Delf; Discussion	63
Meyer, H. S.—On Vote of Thanks ...	246
Meyer, J.—The Alkali Cyanides	91
Microphotographs of Visible Gold in Banket Ore	184
Mill Finger Safety Device. J. M. Dixon	47
Mine Ambulance Competitions	135
Mine Contracts, Stope Cost Records and, of the Anaconda Copper Mining Company. C. L. Berrein	202
— Fires Extinguished by Sealing. D. Bunting	95
— Rescue Apparatus, New Liquid Air. H. Briggs	163
— Timber, The Preservative Treatment of. L. D. Hingle	175
— Waters, The Acidity of. F. W. Watson and R. A. Cooper, 30; Discussion, 32, 159; Reply to	230
Mineral Concentration by Alternate Currents. W. M. Mordy	199
— Identification Sheets and Sieves. C. J. Gray	78
— Land Surveying. J. Underhill. (Book Review)	262
— Phosphate, Sources of Supply of. W. Packard	176
Mineralogy: A Text-book of. E. S. Dana (Book Review)	262
Miners' Consumption. A. J. Lanza and D. Harrington	112
Miners' Nystagmus... ..	264
— Phthisis, Symposium 25, 32,	220
Mines, Metal, Fire Prevention and Fighting in. H. M. Wolflin ...	199
—, Scraping and Loading in. W. Royce	173
Mining Abstracts, 43, 92, 111, 142, 163, 173, 199, 236,	264
Minovici, S. and Jonescu, A.—New Method for the Volumetric Estimation of Copper	197
Miscellaneous Abstracts, 27, 44, 96, 113, 175,	203
Moir, J., at Presentation of Medals ...	46
— —, Determination of Nitrous Fumes in Air	42

	PAGE.
Moir, J.—Estimation of Nitrous Fumes in Air	166
—, —, On the Acidity of Mine Waters	159
—, —, On Miners' Phthisis	230
Moisture in Coal	5
Molybdenum, Determination of.—J. P. Bonardi and E. P. Barrett...	41
Monel Metal	142
—, —, Rapid Method for the Analysis of. P. Covitz	20
Mordy, W. M.—Mineral Concentration by Alternate Currents ...	199
Morel, J. and Wenger, P.—Separation of Silicon, Tin, Titanium and Zirconium by Sodium Carbonate	195
Mozambique Portland Cement Co., Ltd. Plant of, at Lourenço Marques	203
Muller, A.—Resistance of Anthrax Spores to Various Treatments	44
Mulock, F., Clevenger, G. H. and Harris, W.—Dusting and Volatilisation Losses during Melting Cyanide Precipitate and Air Refining of Bullion	198
Mystery Metal, The, Zirconium.—U.S.A. Bureau of Mines	141

N

Neutralisation of Mine Water	30
Newton, S., and Fenster, L. L.—Gold Precipitation by Zinc Dust and in Conjunction with the Degeneration of Solution at Modderfontein "B," 249; Discussion,	253
Newton, S.—On Annual Ballot	217
Nickel Alloys	142
Nitrogen in Coal, Determination of...	10
Nitrous Fumes in Air, Determination of. J. Moir	42
—, —, Estimation of. J. Moir	166
Nominations for Officers	205
Non-Ferrous Metallurgy, Modern Developments in W. R. Barclay	111
Norris, E. M.—Underground Fire Prevention by the Anaconda Copper Mining Company	201
Notes on Osmidium, J. R. Thurlow, 209; Discussion	210
Notices and Abstracts, 19, 26, 40, 65, 89, 107, 136, 162, 166, 194, 233,	263
Nystagmus, Miners'	264

O

Obituaries—	
Dr Alex. Heymann	147, 240
J. Keough	240
J. Martin	147, 240
H. W. Pridgeon	178, 240
Lieut. Col. C. B. Sauer	240
Major L. A. E. Swinney	147, 240
James West	240
Occurrences of Fire Damp on the Far East Rand, T. N. Dewar, Discussion, 34; Reply to	62
Oil Films on Springs and Pools	28

	PAGE.
Oil in Flotation, The Function of. D. W. Leeke and R. H. Jarvis ...	235
—, —, Lubricating, and Grease, Technical Examination of. F. W. Watson and H. D. Bell, 211; Discussion	219
—, —, Mineral, Detecting small Quantities of Petroleum. E. T. Erickson	27
—, —, Rosin	211
—, —, Shales, Retort for Assaying, for Oil Yield. L. C. Karrick	115
Oils, Essential, Eucalypts and their. (Review). E. J. Parry	44
—, —, Mineral, Preparation of Fuller's Earth for Treatment of. W. C. Phalen	26
Ore, Far East Rand, Analysis of. F. W. Watson. Corrigendum ...	19
—, —, Milled, Waste Rock in. W. A. Caldecott, 64; Discussion, 160; Reply to	191
Orenstein, A. J., on Miners' Phthisis, 220, 224,	228
Ormandy, W. R.—Practical Applications of Electro-Endomosis and Cataphoresis	263
Osmidium 70, 152, 173,	209
—, —, A. McL. Reid	70
—, —, Commercial, Uses of	210
—, —, Concentrate, Notes on the Manipulation of. R. A. Cooper, 152; Discussion	154
—, —, in the Banket Reef. R. A. Cooper	78
—, —, Notes on. J. R. Thurlow, 209; Discussion	210
Osmium... .. 70, 78, 152,	210
Owen's and Searle's Lakes, Salts Refining Plants at. L. W. Chapman	89
Oxygen in Solution in Feed Water ...	19

P

Packard, W.—The Phosphate Industry: Sources of Supply of Mineral Phosphate	176
Palladium 70, 78, 162,	173
—, —, Platinum and Gold, Electrolytic Estimation of. W. H. Treadwell	162
Pam, J. E.—On the Endless Rope Haulage at Modder East	187
Papers and Journals	240
Parry, E. J.—Eucalypts and their Essential Oils (Review)	44
Peaty Waters—Detection of Lead in. T. Tickle	194
Percussion Waves, Investigating Strata by	236
Perry, R. W.—Lime Consumption in Cyanidation	162
Petroleum, F. Wantenueiler	115
—, —, (Mineral Oil), Detecting Small Quantities of. E. T. Erickson	27
Phalen, W. C.—Preparation of Fuller's Earth (For Treatment of Mineral Oils)	26
Phosphate Industry, The Sources of Supply of Mineral Phosphate W. Packard	176

	PAGE.
Phosphates, Treatment of, by Calcination with a View to their Employment as Phosphate Fertilisers	90
Phosphoric Acid as Magnesium Pyrophosphate, Determination of. D. Balareff	194
Phosphorus, Leaching Iron Ores for. R. M. Winslow	141
<i>Phthisis, Miners': Symposium, 25, 32, Pilgrim's Rest Gold Fields: Some Notes on the. H. C. F. Bell, 79; Discussion, 85, 160; Reply to ...</i>	220
Pipe, Centrifugally Cast. A. F. Macal-lum	231
Pipes, Incrustation of, Iron Bacteria in Relation to the. D. Ellis	28
Platinum 70, 78, 153, 162, 172, — Crucibles, The Handling of Fusions in. L. L. de Koninck	175
— in 1921. J. M. Hill	209
—, Palladium and Gold, Electrolytic Estimation of. W. H. Treadwell	140
Poisoning, Lead. K. Goadby	172
Portland Cement, Plant at Lourenço Marques	162
Potassium Cyanide, The Acid and Alkaline Decomposition of. G. Harker	170
—, Volumetric Estimation of, and its Application to the Analysis of Fertilisers. G. Anjon	203
Potter, O., and Knox, J.—Gunite in Inclined Shafts	166
Powell, A. R.—A Study of the Reactions of Coal Sulphur in the Coking Process	65
— —. The De-sulphurising Action of Hydrogen on Coke	94
Power Alcohol	40
— Gas from Sewage. J. D. Watson	43
Precipitating Apparatus, Copper, Development of. J. Irving, Jr.	170
<i>Precipitation, Notes on the Influence of Soluble Silica and Calcium Salts on. J. Hayward Johnson; Reply to Discussion</i>	175
—, Quantitative, of Gold by Means of the Electric Current. W. D. Treadwell	110
Preservative Treatment of Mine Timber, The. L. D. Hingle	61
President, The (F. Wartenweiler).— On Action of Controlling Executive of A.S. & T.S.S.A.	107
—, —. On Annual Report	175
—, —. On Application of the Cementation Process to a Battery Foundation	242
—, —. On Associated Scientific and Technical Societies of S.A. ... ..	...
—, —. On Coal Pillar Extraction from Two Seams and Surface Effects	78
—, —. On Contributions towards Maintenance of the Associated Scientific and Technical Societies of S.A.	177
	61
	145

	PAGE.
President, The. On Election of Officers, Associated Scientific and Technical Societies of S.A.	74
—, —. On Essential Services	177
—, —. On Exhibit of Microphotographs of Visible Gold in Banket Ore	184
—, —. On Exhibition and Demonstration of Devices of Practical Advantage	74
—, —. On Ferreira Deep Disaster	147
—, —. On Gold Precipitation by Zinc Dust and in Conjunction with the De-aeration of Solution at Modderfontein "B"	258
—, —. On Index to Journal	248
—, —. On Lecture on Wireless Telegraphy	47
—, —. On List of Members	248
—, —. On Low-Grade Cyanide	206
—, —. On Miners' Phthisis	230
—, —. On Obituaries	147
—, —. On Osmiridium in the Banket Reef	78
—, —. On Publication of the Journal 73, 205,	240
—, —. On Research Endowment Fund: Presentation of Medals	45
—, —. On Some Notes on the Pilgrim's Rest Gold Fields, 79, 87,	161
—, —. On South African Institute for Medical Research	74
—, —. On Technical Examination of Lubricating Oil and Grease	219
—, —. On The Development of the Blast Furnace	184
—, —. On the Revolution	177
—, —. Presidential Address	48
—, —. Vote of Thanks to Prof. J. A. Wilkinson	247
—, —. Welcome to President-Elect Prestea Block A., Gold Coast Colony... ..	246
Prices of Platinum	147
Printing of Journal	172
Problems in Contact Catalysis, Further. H. S. Taylor	73
Proceeding at Ordinary General Meetings:—	26
September, 1921	29
October, 1921	45
November, 1921	73
February, 1922	145
April, 1922	177
May, 1922	205
June, 1922	239
Propellers, Bronze, The Erosion of. O. Silberrard	92
Pump Column Cleaning at the Robinson Gold Mine. Blyth	111
Purifying Air by Electricity	116

Q

Quantitative Precipitation of Gold by Means of the Electric Current. W. D. Treadwell	107
Quick Estimation of Sulphur in Coal	139
Quicklime and Hydrated Lime, Determination of Available Lime in. A. I. Whitson	162,
	168

R	PAGE.	S	PAGE.
Reactions of Coal Sulphur in the Coking Process: A Study of the. A. R. Powell	40	Saccharin in Wine, Detection of. C. von der Heide and W. Lohman ...	166
— of the Xanthates, Notes on Some. —A. Whitby and J. P. Beardwood. Reply to Discussion ...	155	Safety Device, Mill Finger. J. M. Dixon	47
Reagent for Copper, A very Sensitive: The Kastle-Meyer Reagent. P. Thomas	197	Salt Manufacture in Michigan. W. L. Badger	67
— for Mercury Salts, Zinc Purpurate as a.—G. Deniges	264	Salts Refining Plants at Owen's and Searle's Lakes. L. W. Chapman	89
Reagents, Etching	68	Sampling, Analysis and Classification of Coal, A Resumé of Standard Methods in. A. Trevor Williams, 1; Discussion, 36, 155, 189; Reply to	157
Recovery of Zinc from Cyanide Plants	196	Saner, Lieut.-Col. C. B. (the late).—Obituary	260
Refining Plants, Salts, at Owen's and Searle's Lakes. L. W. Chapman	89	Saner, Lieut.-Col. C. B. (the late).—Portrait	237
Refractory Gold Ore, Features of Metallurgy of a. F. Wartenweiler, 147; Discussion	152	Sear Tissue	220
— Substances, Volatilisation of	107	Schlesinger, B.—Notes on an Application of the Cementation Process to a Battery Foundation ...	76
Reid, A. McL.—Osmiridium	70	Schoeller, W. R. and Waterhouse, E. F.—Gravimetric Determination of Bismuth as Phosphate	66
Reim, E. P.—The Combustion of South African Coals in Boiler Furnaces, 117; Discussion, 192; Reply to	258	Schweizer, K.—Alcoholic Fermentation as a Source of Glycerine	167
Report of Council, Annual	239	Scraping and Loading in Mines. W. Royce	173
Research Endowment Fund ... 45, 241	245	Scratches in Material, The Effects of. E. G. Coker	113
— — — —: Presentation of Medals	45	Scrutiners, Annual Ballot, Report of... — for Ballot at Annual Meeting: Election of	246
— in England, Cast-Iron	72	Seamon, H. W.—Air Pressures and Drilling Speeds of Hammer Drills	205
Respirator, Industrial... ..	116	Seaton, M. Y., Hill, C. R., and Stewart, L. C.—Action of Lime in Magnesite Oxychloride Cements ...	95
Resumé of Standard Methods in Sampling, Analysis and Classification of Coal, A.—A. Trevor Williams, 1; Discussion, 36, 155, 189, Reply to	157	Secretary, The.—On Annual Ballot ...	90
Retort for Assaying Oil Shales for Oil Yield. L. C. Karriek	115	—, —, On Annual Report	246
Revenue and Expenditure Account ...	244	Selenium and Tellurium Compounds as Intensifiers of Gasolin	239
Reviews, Book, 41, 161, 165, 233, 261,	262	Selvig, W. A. and Taylor, G. B.—Method for Rapid Analysis of Graphite	195
Revolution, The	177	Separation of Metals of the Second Group. G. G. Longinescu and G. P. Theodorescu	66
Rhodium 70, 78, 153,	210	— of Sphalerite, Silica and Calcite from Fluorspar, The. J. Gross	141
Rickard, T. A.—Concentration by Flo-tation (Book Review)	261	Sewage, Power Gas from. J. D. Watson	175
Rider Stand for Assay Balance. John Watson	218	Shaft Sinking by Caisson A. F. Brosky	203
Ries, H. and Watson, T. L.—Elements of Engineering Geology (Book Review)	161	Shafts, Inclined, Gunite in. J. Knox and O. Potter	94
Road Binding, Coal Tars for Latex	162	Shreve, R. Norris.—Action of Lime on Greensand	66
Robie, E. H.—The Development of the Rod Mill	69	Silbernard, O.—The Erosion of Bronze Propellers	92
Robinson, V. E.—Treatment of Antimonial Gold Ore at the Globe and Phoenix Mine, Southern Rhodesia. Reply to Discussion ...	62	Silica, Soluble and Calcium Salts on Precipitation, Notes on the Influence of. J. Hayward Johnson. Reply to Discussion ...	61
Robinson Gold Mine, Pump Column Cleaning at the Blyth	111	Silicon Tin Titanium and Zirconium, Separation of, by Sodium Carbonate. P. Wenger and J. Morel	195
Rod Mill, The Development of the E. H. Robie	69		
Roll of Honour, The Society's	65		
Rope, Endless, Haulage at Modder East. The J. Chilton, 194, Discussion	187		
Roasting Oil	211		
Royce, W.—Scraping and Loading in Mines	173		
Ruthenium 70, 78, 152,	210		
Rutherford, E.—The Stability of Atoms	195		

	PAGE.
Simmons, C. W., Boehmer, H. C., and Gordon, J. R.—Analysis of Babbit Metal	65
Sinatt, F. S.—On a Resumé of Standard Methods of Sampling, Analysis and Classification of Coal	158
Slime, A Device for Testing the Permeability of. B. L. Gardiner ...	207
Sodium Cyanide	167
— Hydroxide, Carbonate Free, Preparation of. J. Cornog	195
Soils, South African, The Lime Requirements of Some. T. D. Hall ...	139
South African Institute for Medical Research, Johannesburg, Visit to the	135
Sphalerite, Silica and Calcite, The Separation of, from Flourspar. J. Gross	141
Spontaneous Combustion of Coal in Mines	142
Stability of Atoms, The.—E. Rutherford	195
Stainless Iron	169
— Steel	138
Standard Alkali, Guanadine Carbonate as a. A. H. Dodd	42
— Measures, Decimalising. H. Williamson	204
Standardising Works Cyanide Solution, Apparatus and Method for. W. D. Dodds	205
Stanley, G. H.—On the Development of the Blast Furnace	183
<i>Statistics, Metallurgical, The Correlation of.</i> H. A. White, 97; Discussion, 192; Reply to	258
Steel, Iron and, The Corrosion of. J. N. Friend	139
—, Stainless	138
Stevenson, C. and Varley, T.—Chloride Volatilisation Process	71
Stewart, L. C., Hill, C. R., and Seaton, M. Y.—Action of Lime in Magnesium Oxychloride Cements ...	90
Stope Cost Records and Mine Contracts of the Anaconda Copper Mining Company. C. L. Berrein	202
Strata, Investigating, by Percussion Waves	236
Strike, The	165, 177
Students, New	29
Stukofen, The	179
Sulphate of Ammonia from Coal, The Production of. O. Lazar	91
Sulphur in Coal, Quick Estimation of	139
Sweeter, H.—Present Day Iron Blast Furnace Practice	198
<i>Symposium: Miners' Phthisis</i> , 25, 32,	220

T

Taggart, A. F.—Manual of Flotation Processes (Book Review)	261
Tammann, G.—A New Form of Carbon: Carbon Formed by the Action of Mercury on Carbon Tetrachloride, Tetrabromide and Tetraiodide	91

	PAGE.
Taylor, G. B. and Selvig, W. A.—Method for Rapid Analysis of Graphite	66
Taylor, H. S.—Further Problems in Contact Catalysis	26
<i>Technical Examination of Lubricating Oil and Grease.</i> F. W. Watson and H. D. Bell, 211; Discussion	219
<i>Technical Methods of Analysis, Notes on.</i> A. Whitby and J. P. Beardwood. Reply to Discussion	155
Tellurium and Selenium Compounds as Intensifiers of Gasolin	195
Thelma Reef, The	83, 160
Theodorescu, G. P. and Longinescu, G. G.—Separation of Metals of the Second Group	66
Thermometer, Wet and Dry Bulb: A Convenient Humidity Table for the	171
Theta Reefs, The	82
Thiocyanate, Estimation of Small Amounts of Iron as. R. Wilstatter	140
Thomas, P.—A very Sensitive Reagent for Copper: The Kastle-Meyer Reagent	197
Thurlo, J. R.—Notes on Osmiridium, 209; Discussion	210
—, —, Device for Utilising Worn Tube Mill Bars	248
—, —, On Election as Honorary Treasurer	246
Tickle, T.—Detection of Lead in Peaty Waters	194
Timber, Mine, The Preservative Treatment of. L. D. Hingle	175
Tin, Titanium, Silicon and Zirconium, Separation of, by Sodium Carbonate. P. Wenger and J. Morel	195
Titanium, Tin, Silicon and Zirconium, Separation of, by Sodium Carbonate. P. Wenger and J. Morel	195
Treadwell, W. D.—Quantitative Precipitation of Gold by Means of the Electric Current	107
Treadwell, W. H.—Electrolytic Estimation of Gold, Palladium and Platinum	162
<i>Treatment of Antimonial Gold Ore at the Globe and Phoenix Mine, Southern Rhodesia.</i> V. E. Robinson. Reply to Discussion	62
Tube Mill Bars, Worn, Device for Utilising. J. R. Thurlow	248

U

Underground Fire Prevention by the Anaconda Copper Mining Company. E. M. Norris	201
Underhill, J.—Mineral Land Surveying (Book Review)	262
U.S.A. Bureau of Mines.—Zirconium: The Mystery Metal	141

V

	PAGE.
Vacuum Converters	92
Vacuum Drying. The Principles of.— C. O. Lavett and D. J. van Marle	96
Van Marle, D. J. and Lavett, C. O.— The Principles of Vacuum Dry- ing	96
Variability of Metallurgical Results...	103
Varley, T. and Stevenson, C.—Chloride Volatilisation Process	71
Ventilation, Auxiliary. Methods of. D. Harrington and B. W. Dyer ...	43
— Doors in Arizona Copper Mines operated by Compressed Air. E. D. Gardner	164
— of Mines	33
Viscosity of Oils	211
Visible Gold in Banket Ore, Micro- photographs of	184
Visit to the South African Institute for Medical Research	135
Vitamines	263
—, <i>Methods used in the Detection and Investigation of. E. Marion Delf; Discussion</i>	63
Volatilisation, Chloride	43
— Losses, Dusting and, during Melt- ing Cyanide Precipitate and Air Refining of Bullion.—G. H. Clevinger, F. Mulock and W. Harris	198
— of Refractory Substances	107
— Process, Chloride. T. Varley and C. Stephenson	71
Volumetric Estimation of Aluminium. The. E. J. Kraus	167
— — of Copper, New Method for the S. Minovici and A. Jonescu	197
— — of Potassium and its Applica- tion to the Analysis of Fer- tilisers. G. Anjon	65
Von der Heide, C. and Lohman, W.— Detection of Saccharin in Wine	166

W

Wantenweiler, F.—Petroleum	115
War Memorial	242
Wartenweiler, F.— <i>Distribution of Gold in Banket Ore Classified Pro- ducts with Reference to Milling and Cyaniding Operations, Dis- cussion, 24, 35, 106; Reply to Features of Metallurgy of a Refractory Gold Ore, 147, Discussion</i>	187
— <i>Presidential Address</i>	152
— <i>Presidential Address</i>	48
Waste Rock in Ore Milled. W. A. Caledcott, 64, <i>Discussion, 160, Reply to</i>	191
Water, De-gassing and Purification of Boiler Feed. Paul Kottner ...	19
Waterhouse, E. F. and Schoeller, W. R. Gravimetric Determination of Bismuth as Phosphate	95
Watermeyer, G. A.—On Annual Report	243
— On Election as President	246
— On Features of Metallurgy of a Refractory Gold Ore	152
— On Presidential Address	53

Watermeyer, G. A.—On Retirement of Prof. J. A. Wilkinson from Council	PAGE. 247
—, —, On Some Notes on the Pil- grim's Rest Gold Fields	85
—, —, On the Endless Rope Haul- age at Modder East	187
Watson, F. W.— <i>Analysis of Far East Rand Ore; Corrigendum</i>	19
—, —, On Election of Vice-Presi- dents	246
—, — and Bell, H. D.— <i>Technical Examination of Lubricating Oil and Grease, 211; Discussion</i> ...	219
—, — and Cooper, R. A.— <i>The Acidity of Mine Waters, 30; Discussion, 32, 159; Reply to...</i>	230
Watson, John—On Fire Damp in the Far East Rand	34
—, —, On Miners' Phthisis	33
—, —, Rider Stand for Assay Bal- ance	248
Watson, J. D.—Power Gas from Sewage	175
Watson, T. L. and Ries, H.—Elements of Engineering Geology (Book Review)	161
Wenger, P. and Morel, J.—Separation of Silicon, Tin, Titanium and Zirconium by Sodium Carbon- ate	195
West, J. H.—The Claude Ammonia Pro- cess	167
Weston, E. M.—On Automatic Cone Classifier	232
—, —, On Fire Damp in the Far East Rand	35
Westwood, A.—The Assay of Gold Bul- lion	233
Whitby, A. and Beardwood, J. P.— <i>Notes on Some Reactions of the Nanthates; Reply to Discussion</i>	155
Whitby, A. and Beardwood, J. P.— <i>Notes on Technical Methods of Analysis; Reply to Discussion</i>	155
White, H. A., at Presentation of Medals	47
—, —, On an Improved Mercury Bottle	146
—, —, On Device for Utilising Worn Tube Mill Bars	248
—, —, On Distribution of Gold in Banket Ore Classified Products with Reference to Milling and Cyaniding Operations	35
—, —, On Election of Councillors	216
—, —, On Low-grade Cyanide	206
—, —, On Mineral Identification Sheets and Sieves	79
—, —, On Miners' Phthisis	226
—, —, On Notes on Osmiridium	210
—, —, On Presidential Address	53
—, —, On Vote of Thanks	247
—, —, <i>The Correlation of Metal- lurgical Statistics, 97; Discus- sion, 192, Reply to</i>	258
Whitson, A. I.—Determination of Avail- able Lime in Quicklime and Hydrated Lime	168
Wilkes, H. R. S.—On Contributions towards Maintenance of the Associated Scientific and Tech- nical Society of South Africa	146

	PAGE.
Wilkes, H. R. S.—On Features of Metallurgy of a Refractory Gold Ore	152
—, —. On Miners' Phthisis	225
—, —. On Notes on the Manipulation of Osmiridium Concentrate	154
Wilkinson, J. A., at Presentation of Medals	45
—, —. On Retirement from Council	247
Williams, A. Trevor.— <i>A Resumé of Standard Methods in Sampling, Analysis and Classification of Coal</i> , 1; Discussion, 36, 155, 189; <i>Reply to</i>	157
Williamson, H.—Decimalising Standard Measures	204
Wilstatter, R.—Estimation of Small Amounts of Iron as Thiocyanate	140
Wine, Detection of Saccharin in. C. von der Heide and W. Lohman ...	166
Winkler, L. W.—Liquid Air Explosives	26
Winslow, R. M.—Leaching Iron Ores for Phosphorus	141
Wire Ropes of Stainless Steel	139
Wireless Telegraphy, Lecture on	47
Wolflin, H. M.—Fire Prevention and Fighting in Metal Mines	199
Wood, G. B.—The Art of Lime Burning	140
Woodburn, J. A.—On Coal Pillar Extraction from Two Seams and Surface Effects	88
—, —. On Miners' Phthisis	32
—, —. On Some Notes on the Pilgrim's Rest Gold Fields	86

	PAGE.
Woodburn, J. A.—On the Kata-Thermometer	32
Wright, A.—Industrial Filter Cloths ...	176
Wright, L. B.—Geological Methods of the Homestake Gold Mining Co.	174

X

<i>Xanthates, Notes on Some Reactions of the. A. Whittby and J. P. Beardwood; Reply to Discussion</i>	155
---	-----

Y

Y Alloy	142
----------------	-----

Z

Zinc Dust: A New Method for the Evaluation of. Bullenheimer...	166
<i>Zinc Dust, Gold Precipitation by, and in Conjunction with the De-aeration of Solution at Modderfontein "B."</i> S. Newton and L. L. Fewster, 249; Discussion	258
Zinc from Cyanide Plants. Recovery of	196
Zinc, Pure Rolled. The Relation between Mechanical Properties and Microstructure in. D. H. Ingall	70
Zinc Purpurate as a Reagent for Mercury Salts. G. Deniges	264
Zirconium, Silicon, Tin and Titanium, Separation of, by Sodium Carbonate. P. Wenger and J. Morel	195
— The Mystery Metal. U.S.A. Bureau of Mines	141

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1 Mining and Metallurgy
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